ILLUSTRATIONS
OF
USEFUL ARTS
AND
MANUFACTURES.


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ILLUSTRATIONS

OF

Useful Arts and Manufactures.

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INTRODUCTION.

On entering a well-appointed Museum of Natural History, the first impression made on the thoughtful observer, is the *method* which pervades the whole. In becoming better acquainted with the animals, the plants, and the minerals which form the collection, he is made aware of the fact that their methodical arrangement is not for the sole purpose of facilitating study, but that such an arrangement actually exists in nature. An attentive examination of their structure, functions, and conditions of being, causes the various groups of natural objects to fall into their places in the chain of being, and leads to the solemn conviction that their relationship is the result of method, as their existence is of design.

If we were to do for the Useful Arts and Manufactures that which has been done with so much success for Natural History, we should have a Museum of very grand proportions, the contents of which would most impressively illustrate a considerable portion of the history of civilisation. We should see collected therein various specimens of raw material from different parts of the world—the influence of climate or of dissimilar modes of treatment in producing varieties of the same substance—the various changes which the raw material undergoes in passing from its crude state to that of a finished product—the various tools, machines, and engines concerned in the manufacture. We should also have models of workshops with the men at work—models, sections, and drawings of machines; pictorial representations of processes; and in connexion with this vast display would be a library of reference for the use of the student in *Technology*, as we are now accustomed to term the whole business of the Useful Arts.

That such a museum does not exist in a nation so eminently manufacturing as Great Britain, may well excite surprise. Measures, however, are being taken to supply, to some extent at least, the deficiency. Professors of Technology have been appointed in London, Edinburgh, and Dublin, and collections are being formed in those capitals for the purpose of illustrating their lectures.

Supposing such a museum to be in existence, and that we were required to produce a work illustrative of its nature and extent, its scope and object, the result would be much such a work as the reader has now before him. The writer has had considerable intercourse with the manufactories of this country, and by far the larger proportion of the following engravings were made under his direction.

The Useful Arts originated in the necessities of man's nature which required food, clothing, shelter, warmth, artificial light, and thousands of comforts and conveniences, many of which, commencing perhaps with luxuries confined to the few, came in the course of time to be necessaries claimed by the many. As men lived in societies, subdivision of labour would naturally arise; one set of men would confine their attention to the production or preparation of one article only; in course of time they would not only become very skilful in their *handicraft*, a word which itself implies *skill of hand*, but they would also, by constant trials and repeated failures, hit upon the best means and materials for bringing about a certain result. Thus would originate an *art*, or *trade*, or *mystery*, terms which imply—the first, *skill*, the second, *use*, or *experience*, (i.e. *trodden*, or frequently gone over,) and the third, *secrets*, known only to the initiated, and only to be revealed to the apprentice in the course of his seven years' teaching.

In this way originated the more important or indispensable of the Useful Arts, thousands of years before Science had any real existence. They originated, we have said, in the necessities of man's nature, and so far resemble language, hearing, seeing, walking, or any other necessary operation; but it would be difficult to say what share of them belongs to man's intellect, and what to the teaching of a higher power. But for this last influence, there would be many processes in the Useful Arts which could not possibly be accounted for in the absence of Science, and some which even Science cannot yet explain. We are, however, relieved from the necessity of speculating on this point, by the direct information of Holy Scripture. We read (Exod xxxi. 3) that God himself filled

Bezaleel, the son of Uri, with His Spirit "in wisdom and in understanding, and in knowledge, and in all manner of workmanship, to devise cunning works; to work in gold, and in silver, and in brass, and in cutting of stones," &c. (See also ch. xxxvi. 1. I. Kings vii. 14. Isaiah xxviii. 26—29.)

During the long period that Science either did not exist, or existing did not advance, the Useful Arts attained a considerable degree of perfection, and then remained stationary because their object seemed to be attained. Science ceased to advance because she mistook her object; she was lagging behind, investigating the causes of things instead of the laws of phenomena, and it was not until Lord Bacon directed her into this her true path, that Science made progress; but her progress once begun, was rapid. The career of discovery which she is still pursuing with ardour, was graced by numerous gifts to the Useful Arts, which, stimulated by her progress, and encouraged by her example, underwent a great and momentous change—the work of an individual was multiplied a thousand-fold by a machine—the shop became a factory—the power of the hand was replaced by the arm of the steam-engine—power, in fact, became developed with scarcely any limit, and production became all but illimitable. To represent fairly such progress as this, our *Industrial Museum* would indeed require to be of vast proportions, and our *Illustrations* to extend to great length. All we hope and purpose to do, is to afford some glimpses of the great result, and arranging the materials placed at our disposal in methodical order, to give the reader correct information so far as it extends, and a desire to know more on a subject, to which, under Providence, our beloved country owes so much of her greatness and prosperity.

King's College, London,
1858.

I.—COTTON.

THE first object that meets the eye on entering our Industrial Museum is the Cotton Plant; and we shall have no difficulty in explaining how it thus comes to occupy the first rank among our manufactures, when we learn that the cotton consumed in Great Britain in the year 1856 amounted to 920,000,000 lbs., the cost of which was £23,958,000 sterling; that the value of the goods produced amounted to £61,484,000; considerably more than half of which, or goods to the value of £38,275,770, were exported, and of this sum £8,056,671 was received for yarn alone. With such a demand on the cotton-growing districts of America, it is no wonder that the British Government, the manufacturer, and all who think at all on the subject, should contemplate with some uneasiness the prospect of a deficient supply of the raw material. The failure of a single harvest in the United States would indeed be to us a national calamity. Thousands of persons would thereby be thrown out of employment,—not only persons engaged in factories, but sailors and engineers, carpenters and builders, carriers and retail dealers in cotton goods, and many others whose trades and occupations are subsidiary to this vast manufacture;—so mutually dependent are we upon each other's exertions, and all, more or less so, on a due supply of the raw material.

It is curious that such vast machinery, and such vast and complicated results, depend upon the downy covering of an oily seed, which might at first sight appear to have been intended to protect the germ of the future plant, and afterwards to be rejected. We appropriate the covering and reject the seed. A cotton plantation is a nursery for cultivating plants simply for the sake of this downy substance: no other part of the plant being of any commercial value, although cotton-seed oil promises to become so. The country most celebrated for these extensive nurseries of the cotton plant is the southern portion of the United States of America. There are, doubtless, other portions of the world equally well adapted to the growth of cotton, such as British India, parts of Australia, the West Indies, &c. with the advantage of being in our own colonies, and, therefore, more under control than an independent country. But commerce, in spite of British enterprise, is very much a matter of habit, and loves to run in the groove which custom and precedent have worn out for it; so long therefore as America continued to supply the raw material in sufficient quantity, we thought not of deficient harvests, nor of being supplanted by rival consumers, nor of the chances of slave labour in the United States being mitigated, or suppressed, when the conviction shall be forced upon slave owners, as assuredly some day or other it must, that slavery is inconsistent with the Christianity which both black men and white profess. We were satisfied too with the answer to the question, why British India or Australia did not grow cotton, when told, that the one wanted roads, and that the other was an undeveloped country; that in one the natives did not clean and prepare the cotton as we require it, and that in the other there was no labour to be spared.

Within the last two or three years, however, the prospect of a deficient supply and the consequent rise in price, have so alarmed our manufacturers, that earnest attempts are being made to raise cotton in some of our colonies, so that we may no longer be dependent on America for the great bulk of our supply. The total quantity of cotton imported into Great Britain every year was estimated, a few years ago, at about 800,000,000 lbs. Of this quantity, the United States supplied about 635,000,000 lbs., or about 84 per cent. of the total quantity imported; while the East Indies furnished only about 9 per cent.; Brazil, 4 per cent.; Egypt rather more than 2 per cent.; and British Guiana and the West Indies, less than one-tenth per cent. The prices of the cotton varied from 5*d.* to 10*d.* per lb.; but for picked sea-island cotton, as much as 2*s.* 6*d.* per lb. was paid.

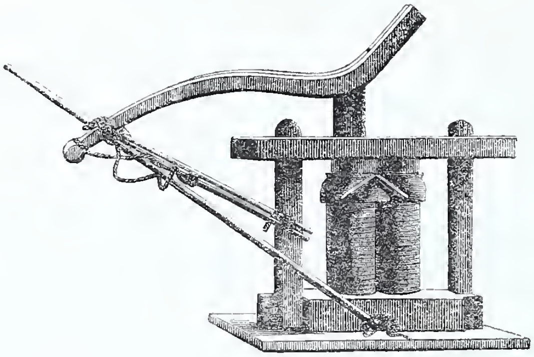
The cotton plant (*Gossypium herbaceum*), fig. 1, grows in India, China, Arabia, Persia, Asia Minor, and some parts of Africa, and is the variety cultivated with so much success in America. It is a member of the order *Malvaceæ*, which contains our common mallow, to which it bears some resemblance: the seed-vessel, however, is different,—the surface of the seed-coat in the cotton plant presenting a thick growth of vegetable hairs or filaments, the length of which, or *length of staple*, as it is called, greatly determines the value of the cotton.

The discovery of cotton wool and cotton fabrics in ancient Peruvian tombs, proves that the cotton plant is indigenous in America. The *G. Barbadense* is the species which has supplied the cotton of North America, and of the West India islands: that of Brazil, Peru, and South America generally, is the produce of the *G. Peruvianum*, a species marked by its black seeds, and their adhering firmly together. From North America, the *G. Barbadense* was introduced into the Mauritius and the Isle of Bourbon, and thence to India, where the plant has become a permanent variety, and its produce is called *Bourbon cotton*. The great bulk of the native-grown cotton is produced from the indigenous species, with little variation either of culture or of manufacture during three thousand years.

The Indian cotton-plant, known to botanists as a distinct species, under the names of *G. Indicum* and *G. herbaceum*, has a wide range in India, growing in the hottest and moistest as well as the driest districts. The varieties arising from soil and climate are all shorter in staple than the American cottons, and in this consists their chief inferiority for the European market. But the Indian cotton has advantages of its own: its colour is good: it takes dye well; and yarns spun with it swell in bleaching, whereby fabrics woven with it acquire a close texture. The famous muslins of Dacca show how fine the manufactures are of which it is capable. In all the varieties the cotton wool fills the seed-pod, and at length causes it to burst, thereby presenting a ball of snowy-white or yellowish down, consisting of three locks, one for each cell, enclosing and firmly adhering to the seeds, which resemble grapes in size and shape. In addition to the herbaceous, there is the *shrub* and the *tree cotton*. A specimen of the latter is shown in fig. 6. But the herbaceous, which is an annual, is the more valuable. The character of its foliage and flower in different stages of maturity, may be further judged of by the border to fig. 5. The cotton plant requires a light sandy soil, and, contrary to the character of most other plants, prospers in the vicinity of the sea. The American sea-island cotton thrives on certain low sandy islands, which extend from Charlestown to Savanna, and is remarkable for its long fibre, and strong and silky texture. The cultivators of Georgia grow three varieties of herbaceous cotton; the first, named *Nankin* cotton, from its yellow colour; the second, *green-seed* cotton; and the third, *sea-island* cotton. The first two grow in the midland and upland districts; and a fine white variety is known as *upland cotton*, or, from a method of cleaning it, *bowed Georgia cotton*. When the cotton is ripe, it should be gathered with the seeds, to the exclusion of the outer husk; for if the whole pod be gathered, the husk breaks into small pieces which cannot be readily separated.

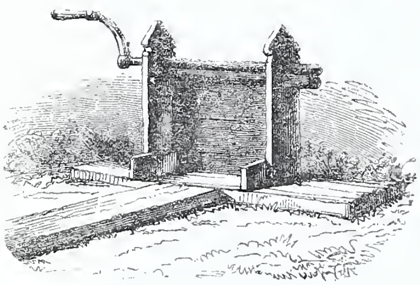
The first preparation which the cotton undergoes is the separation of the seeds, which if done by hand is a slow and tedious operation. Hence, the locks are, in some parts of India and China, passed through a couple of rollers, which being turned by hand, the seeds fly off as the locks pass through. Two of these primitive cotton gins are represented in figs. 2 and 4. The cotton is next cleaned by *bowing*, so called from a large *bow*, suspended in the manner shown in fig. 7, the string of which is made to vibrate in the midst of a heap of cotton, thereby causing the filaments to

1. HERBACEOUS COTTON (*Gossypium herbaceum*).



2. HINDOO COTTON GIN.

3. HINDOO SPINNING WHEEL.

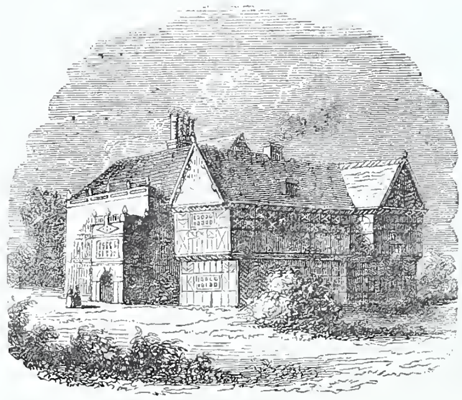


4. PRIMITIVE COTTON GIN.

5. THE SPINNING-WHEEL.

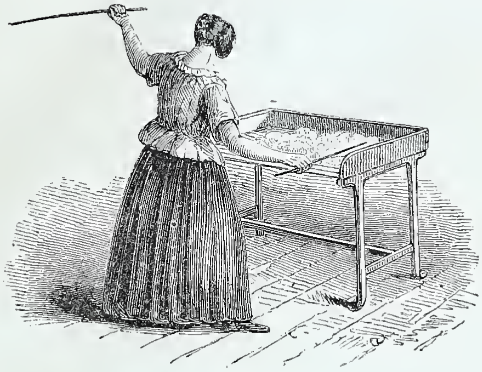
6. TREE COTTON (*Gossypium arboreum*).

7. "BOWING" COTTON.



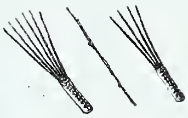
8. HALL-IN-THE-WOOD, NEAR BOLTON.

9. SPINNING WITH DISTAFF AND SPINDLE.

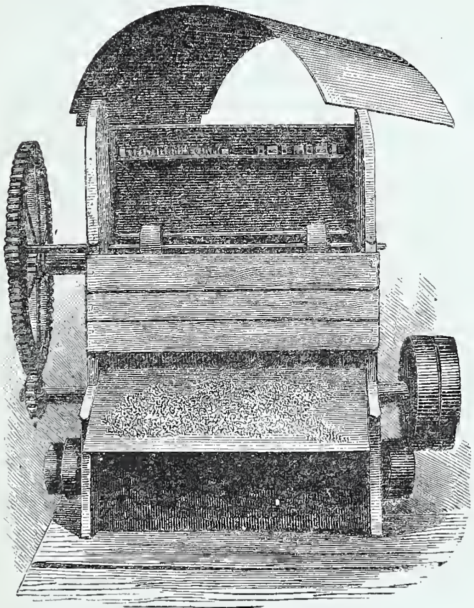


10. BATTING.

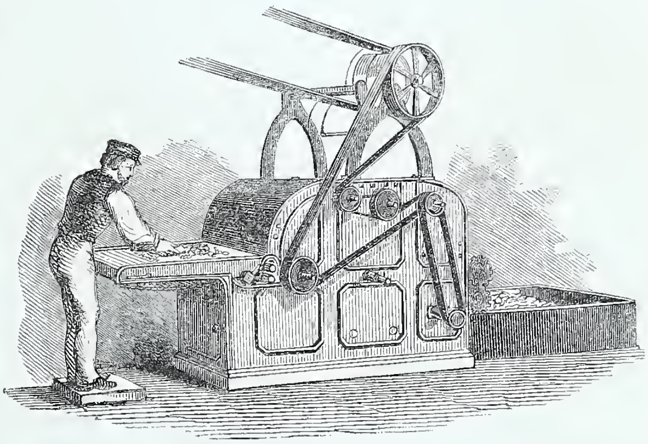
12. FORMING LAPS BY HAND.



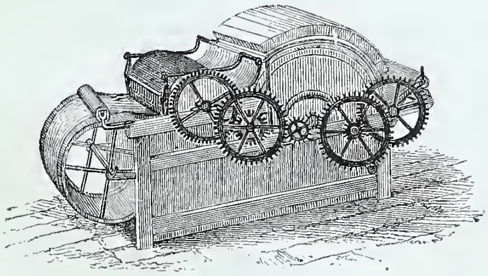
11. FANS USED IN BATTING AND LAPPING.



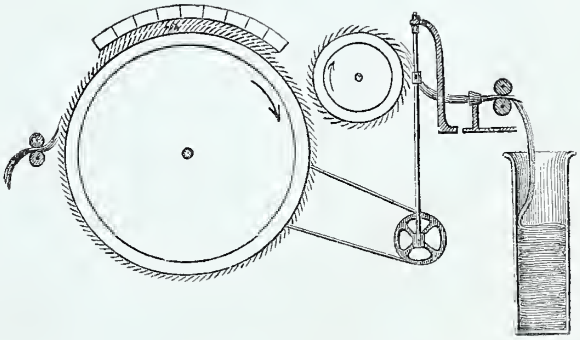
13 OPENING OR COTTON CLEANING MACHINE.



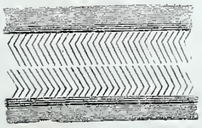
14. OPENING MACHINE.



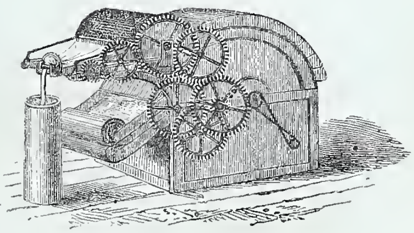
15 FIRST CARDING ENGINE.



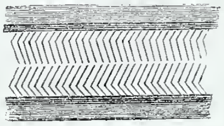
16. WORKING PARTS OF CARDING ENGINE.



18. PORTIONS OF CARDS FOR CARDING.



17 SECOND CARDING ENGINE.



19. PORTIONS OF CARDS FOR DOFFING.

open and disperse in a loose flocculent state, during which particles of dirt escape and fall to the floor. A man can only clean by hand one pound of cotton per day ; but by means of one of these rude machines, the produce of his labour is increased from forty to sixty-five fold. The gin in use in the United States will clean as much as 340 lbs. in a day. This is *Whitney's saw-gin*, in which the cotton is put into a hopper, one side of which is formed by a series of parallel wires, one-eighth of an inch apart. Close to the hopper is a roller, set with circular saws, an inch and a half apart ; and as they revolve they pass between the wires of the hopper, and their teeth seize on the locks of cotton and drag them through the wires, leaving the seeds behind. The cotton is removed from the saws by means of a revolving cylindrical brush.

The two great objects for which a cotton-mill is erected and furnished with much costly and complicated machinery are, first, to place the fibres side by side in parallel lengths, and secondly, to twist them into yarn. These objects were, until towards the latter end of the last century, performed by hand, or with the assistance of the spinning-wheel; and so universally were young females engaged on this employment of spinning cotton into yarn, that the name of *spinster* was applied to them, which they still retain. The most ancient implements were the distaff and the spindle, the one consisting of a stick or reed about three feet long, with a fork near the top, on which the combed or carded cotton was wound, while the spindle was a reed, less than a foot in length, serving as a winder to the thread, the upper part being furnished with a slit for securing the thread, and the lower end having a whorl or wheel for steadying it. Fig. 9 represents an ancient dame at work with the distaff and spindle. She is drawing out a thread from the carded cotton, working and twisting it with her fingers, and imparting every now and then a turn or two to the spindle to increase the twist of the yarn. When the spindle reached the ground a *length* was completed, and the spinster wound it upon the spindle, secured it to the slit, and proceeded with another length.

The natives of Hindostan had for ages a much quicker method than this of spinning cotton yarn. In fig. 3 an attempt is made to represent the Hindoo spinning-wheel; but as the artist who draws machinery does not always understand what he is copying, and has a keener eye for pictorial effect than accuracy of detail, so in the case before us we have a very pleasing picture, but a very inaccurate machine. The large wheel should be furnished with an endless band which should reach as far as the small upright block of wood, and passing over a small wheel therein, set it rapidly in motion, whenever the large wheel is slowly turned by the hand of the spinner. To this small wheel is attached the spindle containing a *cop* or small bundle of cotton, from which the spinner draws out a yarn while it is in the very act of being twisted. The *Jersey wheel* or *Saxon wheel* was introduced into England about the reign of Henry VIII. It is correctly represented in fig. 5, which also shows the mode of working it : its pleasant hum long continued to be a familiar sound in every cottage, and indeed in every house, for fine ladies did not scorn to occupy their leisure with the appropriate work of spinning. The cotton was prepared for the wheel by being first *carded*, combed or brushed with wire-brushes called *hand-cards*, consisting of wire teeth fastened to cards of leather ; two of these are represented on the floor in fig. 5. The fibres being thus made to lay in one direction, the whole of the cotton was divided into a number of soft fleecy rolls or *cardings*, each about a foot in length, and one of these being attached to the spindle, the spinster turned the wheel with one hand and drew out the carding with the other : when drawn out to a sufficient length, it was wound upon the spindle, and another carding being attached was in like manner twisted and drawn out until a continuous *roving* was produced. This was called *coarse* spinning; and in order to produce a tolerably fine thread, it was necessary to spin and draw out the rovings by repeating the process of spinning. In these operations the quality of the thread depended greatly on the skill and delicacy of touch of the spinster. When a firmer and more equal yarn was required, flax was employed; but it was difficult for the spinners to produce the required supply of yarn for the weavers, so that cotton, calicoes, and linens fetched a very high price so long as they were dependent upon the spinning-wheel. About the middle of the last century, a poor but very clever man, named Hargreaves, tried to make the spinning-wheel more productive. He had often tried to spin with several spindles at once, holding the several threads between the fingers of the left hand, but the horizontal position of the spindles interfered with his success. While he was meditating on his favourite subject, one of his children happened one day to upset a spinning-wheel while it was at work, and Hargreaves saw to his surprise that the spindle continued to revolve, and give out yarn in a vertical, as well as in a horizontal position. We do not know why this circumstance should have excited surprise, only we are aware that things which are very obvious when pointed out to us, are obscure enough if left to our own sagacity to discover. The spindle of the spinning-wheel had hitherto all the world over revolved in an horizontal position, and now it was seen for the first time to revolve vertically. Hargreaves took the hint; the thought occurred to him that if a number of spindles were placed upright and side by side, a number of threads could be spun at one time. Accordingly he contrived a frame with eight spindles in a row, and eight rovings being attached to them, the loose ends were placed within a fluted wooden clasp, which when shut held them tightly: this clasp was drawn by the left hand along the frame to a distance from the spindles, while the spinner with his right hand turned a wheel, which by an endless band set a drum in motion, and the latter in its turn also, by means of endless bands, set all the spindles spinning. Eight lengths being thus spun, the clasp was returned to its original position; the spindles being at the same time made to revolve gently, the finished yarn was wound upon them ; the clasp being again opened, fresh lengths of rovings were attached and spun out as before. The number of spindles set in motion in one frame was increased from 8 to 80. Such is the origin of the famous *spinning-jenny*, a representation of which will be found among the spinning apparatus further on (see fig. 31) ; but we may mention that the word *jenny* or *jinny*, is from *gin* or *engine*, the new machine being called a *ginny*, and the process *ginning*. The writer of these pages was informed by a grandson of Hargreaves, that the term originated in a remark made by the wife of the inventor to her daughter Mary, who was spinning with the new frame : " Thou *gins* away famously." It is commonly said, that the word *jenny* was named after Jane, one of the inventor's daughters. Hargreaves kept his discovery secret for some time, but the quantity of cotton spun by his family excited suspicion, and the spinners broke into his house and destroyed his machine. On this Hargreaves removed to Nottingham, where he erected a small mill on the jenny plan. He took out a patent for his machine; but having sold several machines before he thought of applying for legal protection, his patent was of no use to him, and the spinning-jenny became the property of the nation.

The next great inventor in the art of spinning cotton by machinery, was a poor barber, named Richard Arkwright, who becoming acquainted with a clockmaker named Kay, probably received from him the crude idea of drawing out the cotton by passing it between several pairs of rollers, moving at different and increasing rates of speed. Several names are mentioned in connexion with this great invention, but it is certain that Arkwright, if not the inventor, was the perfector of the invention. Add to this the invention of a young weaver, named Samuel Crumpton, who combined the spinning-jenny of Hargreaves with the roller spinning of Arkwright in a machine called the *Mule* or the *mule-jenny*, and we have the three great inventions of this manufacture. In the last-named machine, the spindles, instead of being stationary, were placed on a movable carriage or mule, which was wheeled out to the distance of about five feet in order to stretch and twist the yarn, and was wheeled in

again, in order to wind it on the spindles. Crumpton was a weaver by trade, and occupied a picturesque old mansion in a retired and beautiful spot near Bolton. This house, named *Hall-in-the-wood*, is represented in fig. 8. Crumpton's object in his invention was to supply his own loom with good yarn, but he could not keep his invention to himself: persons climbed up to his windows to watch him at work, and the mule not being protected by patent soon came into general use. The first machine was constructed for some 20 or 30 spindles, but mules are now made to carry from 2,000 to 3,000 spindles.

The southern part of Lancashire, with Manchester for its capital, is the chief locality of the cotton trade; the site having been determined by the abundance of what may be called the sinews of manufactures, viz. water power, fuel, and iron; for with these, machinery may be manufactured and set in motion at the smallest cost, and many of the finishing processes for textile fabrics, depending as they do on the agency of water and heat, may be conducted with advantage.

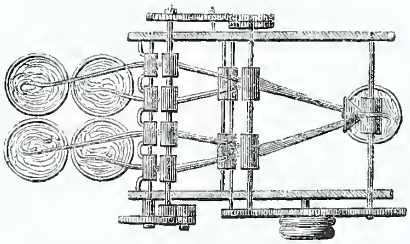
Let us now trace the progress of a bale of cotton through a cotton-mill, until it is sent out again in the form of a bundle of yarn. Liverpool is the great mart for raw cotton, and here the cotton spinners resort to purchase it. The bags or bales are sent by rail to Manchester, and the first operation in the mill is to unpack and to sort. In order to insure a cotton of one quality, the bags as they are opened are spread in layers one above the other, forming what is called a *bing* or *bunker;* and when the cotton is taken for the various operations of the mill, it is raked away from the vertical side of this cotton stack, by which means a certain quantity of each bag is made to mix up and blend with the other bags, the result being an equal quality from specimens which differ somewhat in quality. The locks of cotton being tangled in the gathering, and matted together by pressure in the bale, and moreover being somewhat dirty, are now opened and cleaned. If the cottons are of fine quality intended for fine spinning, they are beaten or batted by hand as shown in fig. 10, with twigs of hazel or holly, three or four feet long. In this operation the cotton is placed upon a frame, the upper surface of which is made of cords, so as to form a kind of elastic grating; and as the cotton is violently beaten, the tangled locks become opened, the dust and loose impurities fall to the ground between the cords, but the fragments of seed-pods which adhere firmly are picked out by hand. The cotton thus cleaned is spread in a known weighed quantity, upon a length of canvas contained in a frame as shown in fig. 12, and is made to lie pretty evenly thereon, by means of fans of wood shown in fig. 11, after which the whole is rolled up into a *lap* for supplying another machine. For the ordinary purposes of common spinning, the cotton is opened and cleaned in a machine called a *willow* or cotton cleaning machine, fig. 13. The cotton is placed upon an endless apron, the motion of which feeds a couple of rollers which are furnished with coarse teeth: these seize the cotton, draw the locks apart, and pass them on to other rollers with finer teeth, by which the fibres are further opened, while the impurities are thrown out at the bottom. Some of the rollers revolve at the rate of about 500 turns per minute. In another machine, fig. 14, the cotton is held and delivered slowly by a pair of rollers, during which it is subjected to the blows of beaters arranged like the spokes of a wheel and revolving with great rapidity, by which means the particles of sand, dirt, &c., are shaken out, while the flakes of cotton are wound upon a roller in such a way as to form a continued sheet of a loose fleecy texture, also called a *lap;* the same, in fact, as was done by hand in fig. 12.

The laps thus formed are made to feed the first *carding-engine*, where the fibres are further separated and disentangled, freed from the remaining impurities, and an approach is made to parallelism. A cotton card is a sort of wire-brush, consisting of bent pieces of hard drawn iron wire, called *dents* or *teeth*, fixed into a band or fillet of leather, or of a compound of cotton, linen, and india rubber. These fillets are made to cover the surface of drums of various sizes, and the cotton is combed out upon these drums, and transferred from one to another in a manner which we will now briefly explain.

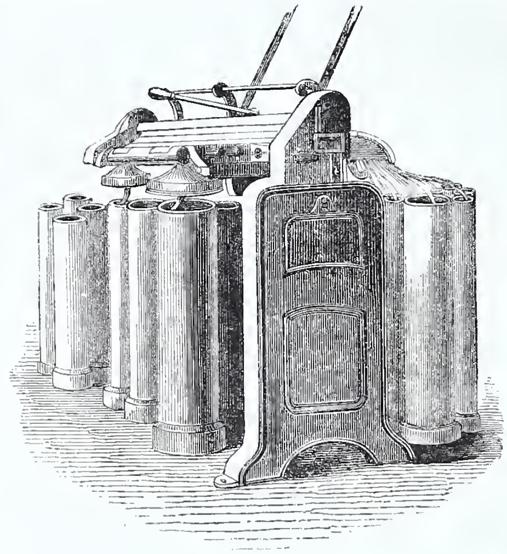
Fig. 18 represents a portion of two combs, with the teeth placed in opposite directions: if a tangled lock of cotton wool be placed on the lower card, and this be moved towards the left, while the top card is moved towards the right, and the operation be repeated a number of times, it is obvious that the lock will be disentangled and combed out, and the fibres laid side by side in parallel order, or nearly so. The lock will, however, be buried among the teeth of the comb; and in order to disengage it, all that is necessary is to reverse one of the cards, as in fig. 19, and moving one upon the other, the lock will be removed from the lower card to the upper. We shall now be able to understand the action of the carding engine, the working parts of which are represented in fig. 16. On the left hand side the lap is seen approaching the large drum of the carding-engine between a couple of rollers. The drum, moving upon its centre in the direction of the arrow, takes up the fibres of the lap and distributes them over its surface, and they are combed out by means of a number of straight pieces placed over the drum and furnished with teeth bent in an opposite direction to those of the drum. As the fibres come round, they are taken up by a smaller drum, moving in an opposite direction to the large drum, from which they are removed in the form of a delicate fleece by means of a doffing comb, to which a rapid chopping motion is imparted by attaching the rod which bears it to a crank, or to a point a little out of the centre of the wheel which gives motion to the comb. As the web is removed from the small drum, it is drawn through a cone-shaped piece of metal: it is then passed between a couple of rollers, which condense it somewhat, and it is lastly received into a can, in which it coils itself up in a spiral form. It is now called a *card-end*, or *sliver*. In fine spinning, the cotton is passed through two carding-engines, the first being called a *breaker-card* (fig. 15), and the second a *finishing-card* (fig. 17), in which the teeth are set finer than in the former.

The spongy slivers from the carding-engine are next passed between rollers revolving at different rates of speed, for the purpose of straightening the filaments, unfolding such as are doubled, laying them side by side in parallel order, and by uniting a number of slivers and drawing them out into one, serving to correct the defects of individual slivers. The *drawing-frame* (figs. 20, 21, 22) usually consists of three pairs of iron rollers, the upper one of each pair being covered with leather, while the lower are fluted in the direction of their length: the upper ones are also weighted so as to produce considerable pressure. The under rollers are driven by wheel-work at various rates of speed, and they cause the upper ones to revolve by friction. At the back of the machine are placed the cans full of slivers, and a number of these are guided usually along a channelled surface to the rollers, where they are united, and the sliver, thus doubled many times, is drawn out, in passing through the rollers, into a uniform sliver of greatly increased length, which is also coiled up in a can placed for its reception. The drawing is usually repeated a number of times: for example,—for coarse spinning, six card-ends are usually passed through the first drawing-head and formed into one riband; six of these ribands are again drawn and doubled into one; six of these are formed into a third sliver, and five of these are passed through the last drawing-head; so that the doubling of the fibres of the carding has been multiplied $6 \times 6 \times 6 \times 5 = 1080$ times. For fine spinning the drawings are carried to a much greater extent.

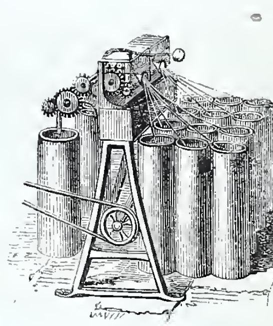
The cotton as it leaves the drawing-frame is in the form of a loose, porous cord, the fibres of which are parallel. It is too thick to be spun into yarn, and too tender to be further reduced in size by further drawing alone; if, however, a slight twist be given to it, the fibres will be made a little more compact, and the drawing may be proceeded with. This double process of drawing and twisting is called *roving*. The *roving-machine*, in its simplest form (figs. 24, 25), consisted of two pairs of drawing-rollers for



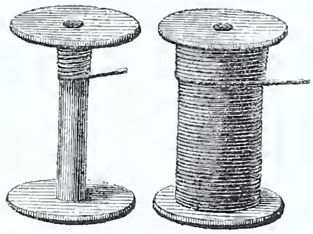
20. DRAWING (4 INTO 1).



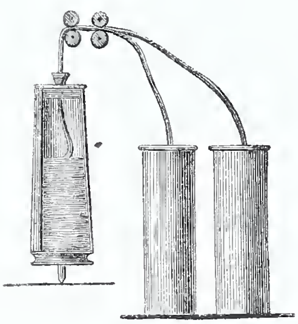
21 DRAWING FRAME.



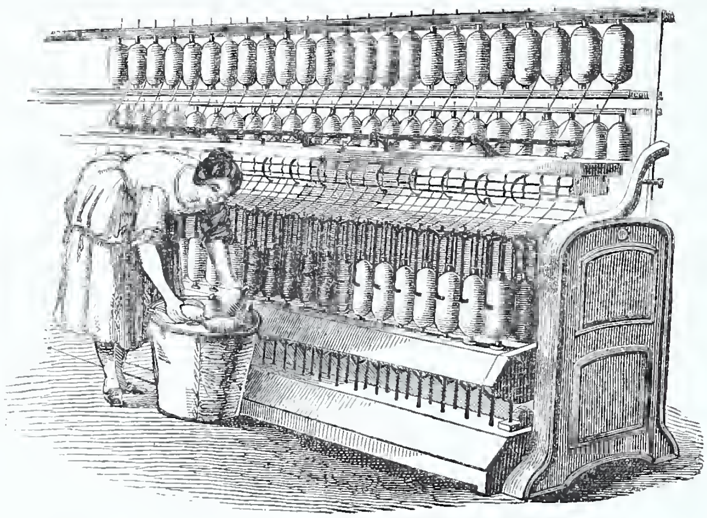
22 DRAWING (12 INTO 1).



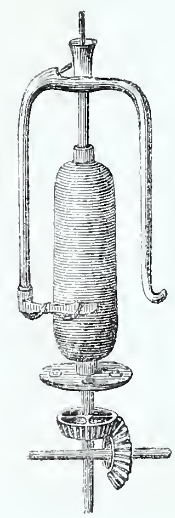
23. BOBBINS.



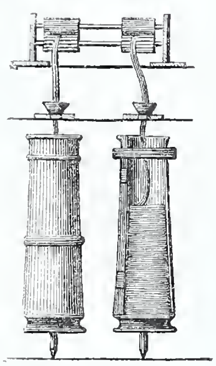
24. ROVING.



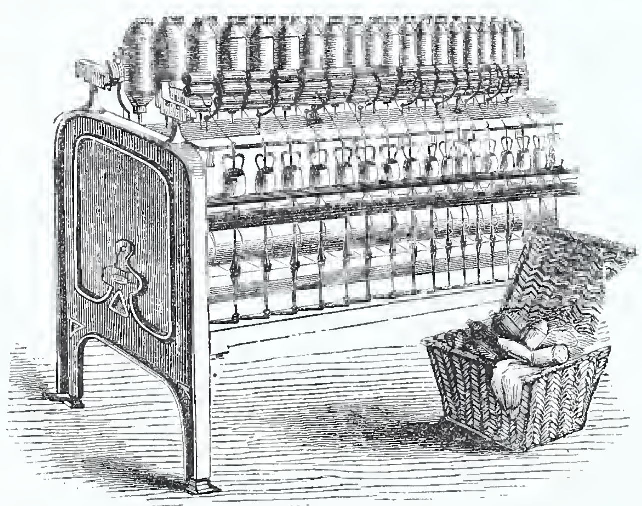
26. ROVING FRAME.



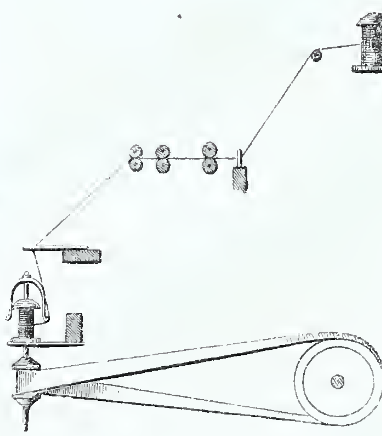
27. BOBBIN, FLY AND SPINDLE.



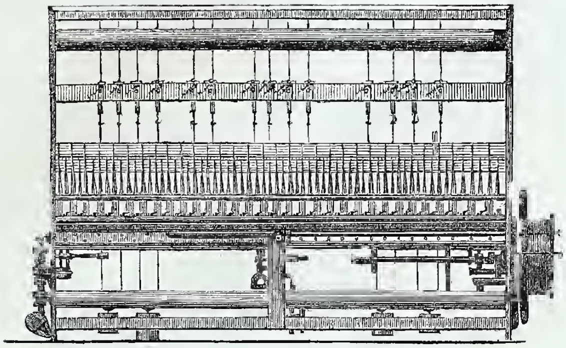
25. ROVING.



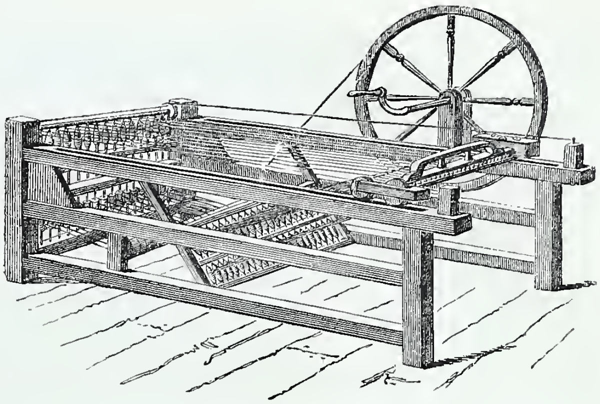
28. COMMON THROSTLE.



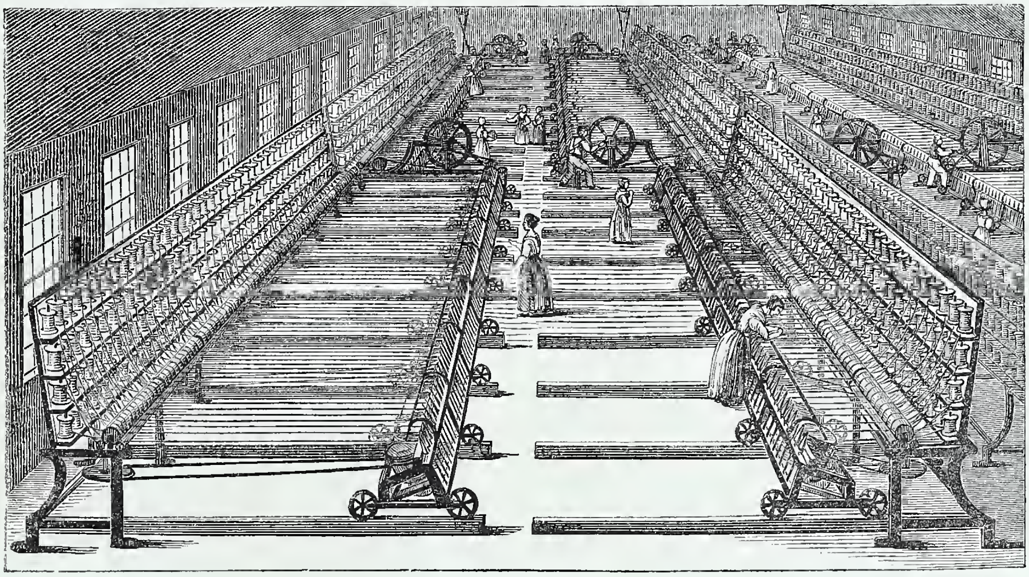
29 WORKING PARTS OF THE THROSTLE.



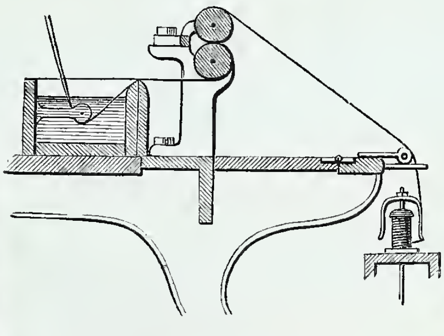
30. IMPROVED THROSTLE.



31. HARGREAVES'S SPINNING JENNY.

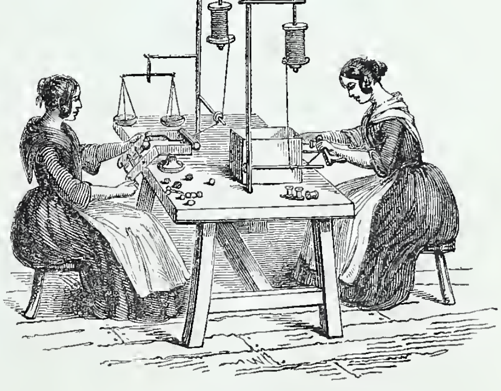


32. MULE SPINNING.

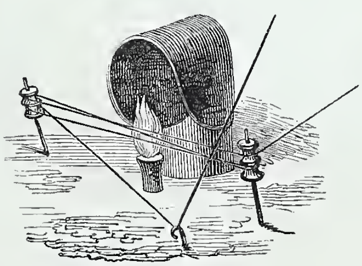


35. SECTION OF THREAD FRAME.

33. REELING.



36. BALLING AND REELING.



34. GASSING THE YARN.

extending the slivers, of which two were generally doubled and united, and the sliver as it quitted the drawing-rollers was received into a can which was made to spin rapidly round, thereby giving a slight twist to the sliver, and thus forming the roving. The roving had next to be wound upon bobbins, which was done first by hand, and afterwards by what was called a jack-frame; this led to the *bobbin-and-fly-frame*, which is the roving-machine now in use. The object of this machine is to give the slivers a slight twist, and then to wind them on the bobbins. The twist is accomplished by the revolutions of a spindle; the winding is a more complex operation. The spindle of which we are now speaking is a round steel rod, a portion of which is shown in fig. 27; and it is made to revolve rapidly by means of the small cog-wheels, one of which is attached to the spindle itself, and the other, which is in gear with it, is attached to a horizontal rod, which derives its motion by being in gear with one of the main moving shafts of the mill, which latter, of course, derive their motion from the steam-engine of the establishment. The bobbin may be of the shape represented in fig. 23, or it may consist simply of a piece of hollow tube: it is threaded upon the spindle, and the small bed or platform on which it rests is made to revolve by another series of wheels, not shown in the figure. The spindle has two arms, called the *fly* or *flyer:* it fits by a square or six-sided hole to the top of the spindle, and can be removed in an instant when it is required to put on or take off the bobbin. One arm of the fly is hollow, and the other solid; and the roving-frame (fig. 26) may contain 100, 200, or more spindles, in a double row. This arrangement being understood, the action of the machine is as follows: —The sliver, having been drawn by the rollers, is twisted by the rapid revolution of the spindle into a soft cord, or roving; this enters a hole in the top of the spindle and passes down the hollow arm of the fly; it is then twisted round a steel finger, as shown in fig. 27, which winds it on the bobbin with a certain pressure. In order to wind the roving evenly on the bobbin, the delivering finger is made to move up and down, or rather the bobbin is made to slide up and down on the spindle, an effect which is produced by causing the bed upon which the bobbins rest to have a slow rising and falling motion. It is further necessary, as the winding proceeds and the bobbin increases in thickness, that the spindle should slightly diminish its speed, otherwise the roving might be improperly stretched or broken: this is effected by causing the strap which connects the motions of the moving shafts to act on a conical, instead of a cylindrical drum, so that by properly moving the strap along its surface a varying rate of speed is insured. It will be understood that the spindle and the bobbin are driven at different rates of speed, for if they both moved at the same rate, the roving would be twisted merely, and not wound upon the bobbin; but by making the bobbin revolve a little quicker than the spindle the winding is accomplished. For example, if the bobbin revolve fifty times and the spindle forty, forty turns of the bobbin will have nothing to do with winding; but there are ten turns of the bobbin above those of the fly which will perform the winding. Hence, forty turns of the spindle produce twist, while fifty turns of the bobbin wind ten coils of the roving upon its barrel.

There are two sets of bobbin-and-fly frames, viz. the *coarse* and the *fine*, or the *first* and the *second* roving-frames: they are the same in principle, only the first has fewer spindles, and is fed with slivers from cans filled at the drawing-frame and placed at the back of the machine. The second roving-frame is fed with rovings, or, as they are sometimes called, *slubbings*, from bobbins filled at the first roving-frame: these bobbins are arranged on upright skewers, fixed in a shelf or creel placed behind the roller-beam, as shown in fig. 26. The roving from these bobbins is made to pass through wire eyes, to prevent it from being torn obliquely from the bobbins. In fig. 26, the most important part of the apparatus, namely the roller-beams, is not made out, but the position of the rollers will be understood by referring to figs. 24, 25, and 29. It should be mentioned, that before the sliver enters the back pair of drawing-rollers, the guides through which it is led having a slow side motion to and fro, shift the sliver alternately to the right and to the left about three-quarters of an inch, to prevent the leather covering of the top rollers from becoming worn or indented by the sliver passing constantly over the same line of surface. The bobbin-and-fly frame is superintended by a female, whose duty it is to join the broken slivers, to remove the full bobbins, and to place empty ones in their stead.

The rovings are usually finished either at the *throstle* or at the *mule-jenny*. In the throstle (figs. 28, 29), the roving from each bobbin passes through three pairs of drawing-rollers, by which it is extended to the requisite degree of fineness. On coming out of the last pair of rollers, each roving is guided by a small ring, or a notch of glass let into the frame towards the spindles; these revolve with great rapidity, so that the flyers make a low musical hum, which is said to have given the name of throstle to this machine. The roving, or *yarn*, as it may now be called, passes through an eyelet at the end of one of the arms of the fly, and proceeds to the bobbin, on which it is wound by the following contrivance. The bobbin fits loosely on the spindle, and one end rests upon a shelf. As soon as the fly is set spinning, the yarn drags the bobbin after it, and makes it follow the motion of the spindle and fly; but the weight of the bobbin, and its friction on the shelf, cause it to hang back somewhat, the effect of which is to keep the yarn stretched, and to wind it on the bobbin much more slowly than the fly revolves. The yarn is equally distributed on the bobbin by giving it a slow up and down motion. Thus it will be seen that the throstle is similar to the bobbin-and-fly frame, only in the latter the bobbin is made to revolve by a distinct movement, while in the former the pull of the yarn, which is now sufficiently strong, produces the effect. The throstle spins a strong, wiry thread, well adapted for *warps*, as those threads are called which represent the length of a piece of woven cloth. The throstle does not spin very fine yarn, because this would not bear the drag of the bobbin; fine yarn therefore is usually spun at the mill.

The spinning-mule (several of which are shown in fig. 32, which represents a portion of one of the floors of a cotton-mill at Manchester) consists of two principal portions: the first, which is fixed, contains the bobbins of rovings, and the drawing rollers; the second is a sort of carriage moving upon an iron railroad, and capable of being drawn out to a distance of about five feet from the fixed frame. This carriage carries the spindles, the number of which is half that of the bobbins of rovings. Motion is given to the spindles by means of vertical drums, round which are passed slender cords, communicating with the spindles. There is one drum to every twenty-four spindles.

The carriage being run up to the point from which it starts in spinning, the spindles are near to the roller beam; the rollers now begin to turn and to give out yarn, which is immediately twisted by the revolution of the spindles; the carriage then moves away from the roller beam, somewhat quicker than the threads are delivered, so that they receive a certain amount of stretching, a circumstance which gives value to this machine. The beneficial effect is produced in this way; when the thread leaves the rollers it is thicker in some parts than in others, and those thicker parts not being so much twisted as the thinner ones, are softer, and yield to the stretching power of the mule so that the twist is equalized throughout, and the yarn becomes more uniform. When the carriage has completed a *stretch*, or is drawn out from about 54 to 64 inches from the roller beam, the drawing-rollers cease to give out yarn, but the spindles continue to whirl until the threads are properly twisted. In spinning the finer yarns, the carriage sometimes makes what is called a *second stretch*, during which the spindles are made to revolve much more rapidly than before. The drawing, stretching, and twisting of a length of thread being thus completed, the mule disengages itself from the parts of the machinery by which it has hitherto been driven, and the spinner then seizes the carriage with his left hand, and pushes it back to the roller beam,

turning at the same time with his right hand a fly wheel, which gives motion to the spindles. At the same time a *copping wire*, as it is called, is pressed upon the threads by the spinner's left hand, and they are thus made to traverse the whole length of the spindle, upon which they are then wound or *built* in a conical form which is called a *cop*. These cops are used for placing in the shuttle in weaving, and form the *weft*, or short cross threads of the cloth.

One man is able to attend to two mules, guiding in the carriage of one mule by hand, while the carriage of the other is being moved out by the steam engine. Much skill is required in pushing back the carriage. As a preparatory step, the spinner causes the spindles to revolve backwards for a moment to slacken the threads just completed, and throw them off the points of the spindles previous to winding them. In pushing the carriage back he must attend to three things; he must guide the copping wire so as to insure the regular winding of the yarn on the cop; he must regulate the motion of the spindles, and he must push the carriage at such a rate as to supply the exact amount of yarn that the spindles can take up in a given time.

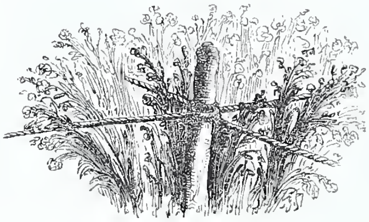
The spinner is assisted by boys or girls to piece the broken threads. He also employs a *scavenger* to collect all the loose or waste cotton, called *fly*, which lies on the floor, or hangs about the machinery. This is afterwards used chiefly in cleaning the machinery. It is calculated that the waste from the different machines in spinning cotton, amounts to $1\frac{1}{2}$ oz. per lb. or nearly $\frac{1}{10}$th of the original weight. It is the duty of the piecer to join the broken ends of the threads as the carriage moves from the upright frame. The breaking of the thread depends, in some degree, on the temperature and the state of the atmosphere. During an east wind the threads sometimes break faster than the piecers can join them, and it seems probable that the rapid whirling of so many thousand pieces of machinery, produces in very dry weather a large amount of electricity, which may prevent the proper spinning of the fibres. At such times it is not uncommon to keep the atmosphere of the room moist by jets of steam, and to maintain a temperature of from 68° to 76°. Indeed, fine yarn cannot well be spun at a lower temperature.

The self-acting mule does the work of the spinning mule without the assistance or attendance of any one except the piecer. It is one of the most extraordinary machines in the cotton manufacture.

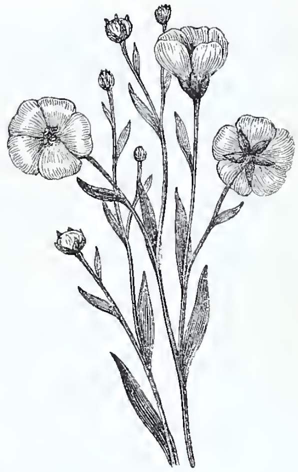
It will be understood from the foregoing description, that throstle-yarn is wound upon bobbins, while mule-yarn is formed into cops. If this yarn is intended to form the warp, or length of a woven piece, it is wound off into measured lengths of 840 yards each. These are called *hanks*. The reel for winding and counting hanks (fig. 33) is six-sided. It is a yard and a half in circumference, and is mounted in a carriage which carries the spindles or skewers that bear the bobbins or cops. The carriage has a slow traverse motion, parallel to the axis of the wheel, for spreading the thread upon its surface. When the wheel has completed 80 turns, a check is struck, showing that a *ley* or *rap* of 120 yards has been formed: seven of these raps make a hank of 840 yards. The woman who minds the machine ties the hanks round with a string, slips them off the wheel, and proceeds to wind another set. The size of the yarn is ascertained by weighing the hanks, and applying the following rule:—Divide 1000 grains by the number of grains in a ley, and the quotient will give the number of hanks to a pound. This rule is based on the fact that a ley is one-seventh of a hank, and 1000 grains equal to one-seventh of a pound. The average number of hanks to the pound is, for coarse spinning, from ten to forty: for candle-wicks, coarse counterpanes, &c. such low numbers as two hanks to the pound are manufactured. In the Great Exhibition of 1851, yarns of the degree of fineness represented by No. 600 were exhibited; and, as a matter of curiosity, small specimens of various degrees of fineness, up to 2150 and even 2170, were shown. Such yarns are, of course, very costly; indeed, it is not uncommon for lace-makers to pay 100 guineas and upwards per pound for their thread.

Fine yarns are disfigured by a number of minute, loosely projecting fibres, which must be removed before they can have that level, compact appearance which is required in the manufacture of bobbin-net lace thread, and for hosiery. This is done by passing the yarn rapidly through a gas flame, as shown in fig. 34, whereby the loose filaments are completely burnt off, and the yarn is improved in appearance and value.

When two or more yarns are twisted together, they form what is properly called *thread*. There are various kinds of thread, such as *lace-thread, stocking-thread, sewing-thread*, &c. The machine for doubling and twisting yarns into thread (fig. 35) resembles the throstle, already described (fig. 29). The yarns are unwound from bobbins or cops, and are then led through a very weak solution of starch, which enables them to be twisted into a more solid thread, and on emerging from the trough, the yarns, to the number of two, three, four, or six, according to the required size of the thread, are guided between a couple of rollers, which lay them parallel; they are then passed down to the eyelet of the flier, the rapid revolutions of which twist them into a solid cord or thread, which is wound upon the bobbin. The twist usually given to the doubled yarns is in an opposite direction to the twist of the individual yarns. The thread is made up into hanks for dyeing or bleaching, after which it is wound upon bobbins, for the purpose of being made up into balls or wound upon reels (see fig. 36).

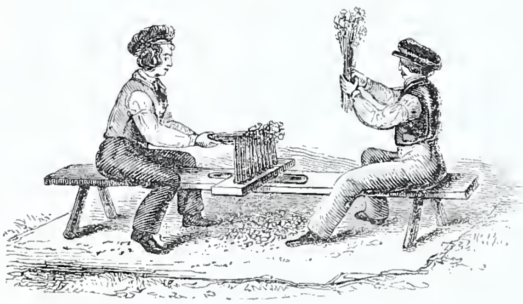


38. METHOD OF SUPPORTING FLAX.

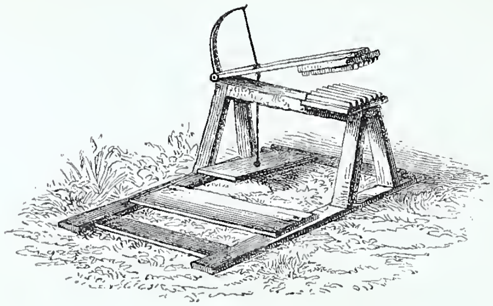


37. THE FLAX PLANT.

39. SHEAVES OF FLAX.

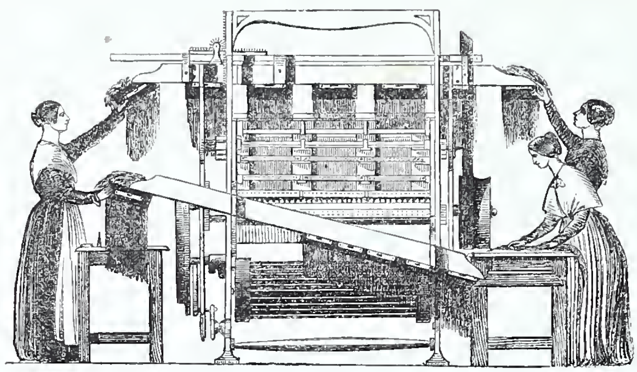


40. RIPPLING.



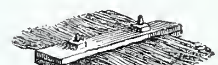
1. THE BRAKE.

42. SCUTCHING FRAME.

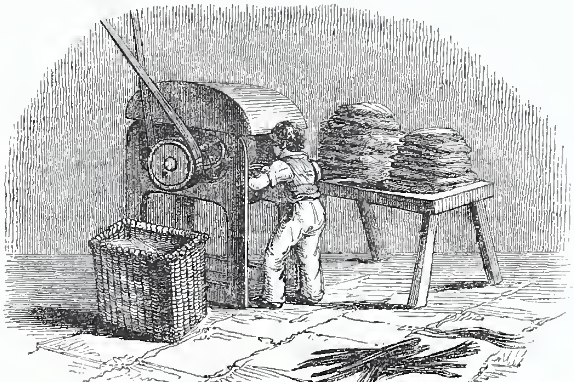


44. BRUSHING MACHINE.

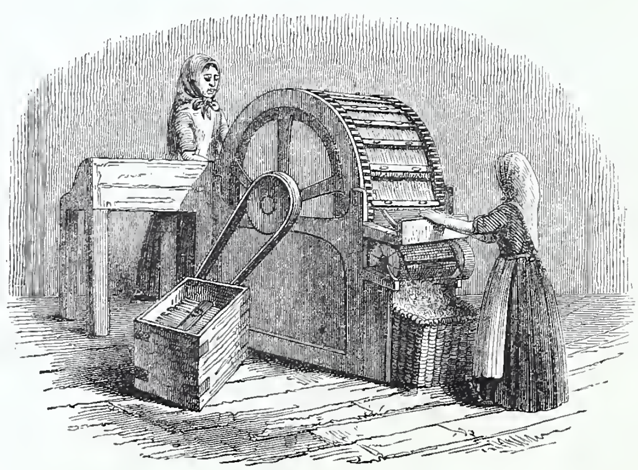
43. THE SCUTCHER.



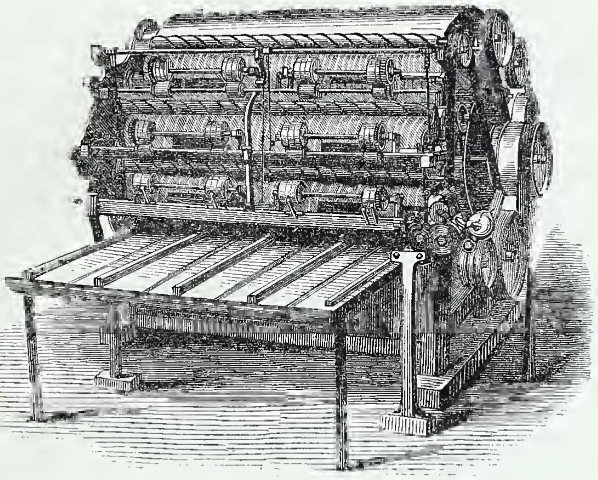
46. HOLDER.



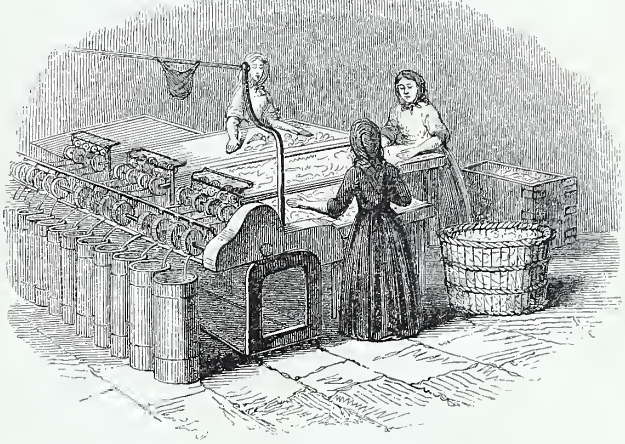
45. DIVIDING THE FLAX INTO LENGTHS.



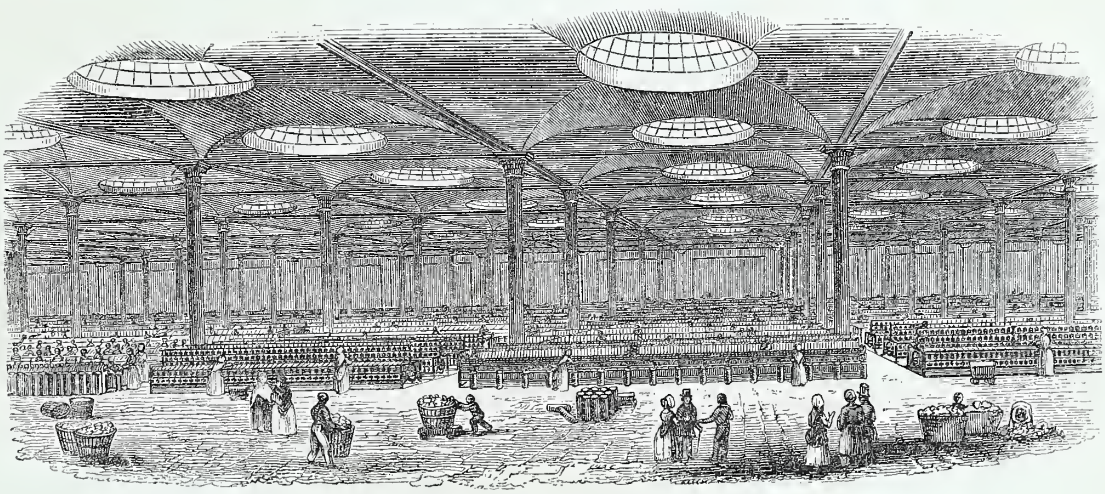
47. HECKLING MACHINE.



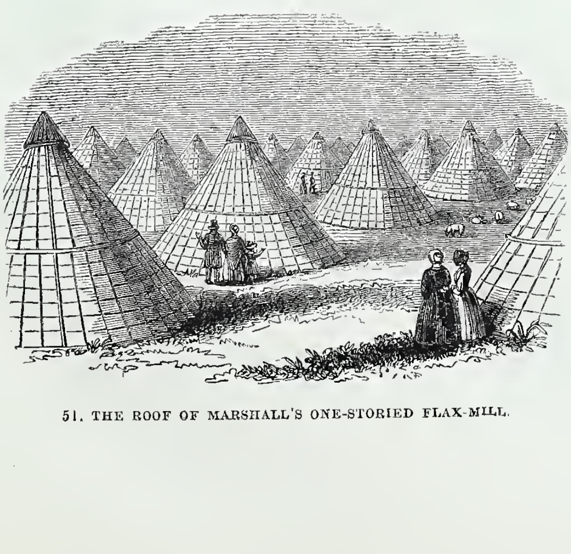
48. TOW CARDING ENGINE.



49. SPREADING-FRAME.



50. INTERIOR OF MARSHALL'S ONE-STORIED FLAX-MILL AT LEEDS.



51. THE ROOF OF MARSHALL'S ONE-STORIED FLAX-MILL.

52. THE FLAX SPINNING-WHEEL.

II.—FLAX.

Of the four great materials of clothing, and other textile fabrics, viz. cotton, linen, silk, and wool, linen is one of the most ancient. The art of preparing the fibres of flax and weaving them into linen cloth, had reached a high degree of perfection among the Egyptians so early as the time of Joseph, for we read (Gen. xli. 42) that Pharaoh arrayed Joseph in vestures of fine linen, while specimens of the very same fine linen are occasionally brought before our notice on partially unrolling some of the mummies which have been removed from their original place of sepulture to swell the crowd of curiosities in our museums.

The flax plant (*Linum usitatissimum*, fig. 37) is an annual. It sends up slender fibrous stalks two or three feet high, with narrow alternate leaves and delicate blue flowers; these are succeeded by globular seed-vessels, the cells of which enclose bright slippery brown flattened and elongated seeds called *linseed*, which furnish the well-known oil. The stalks are hollow tubes, the filaments of which supply the material for cambric, linen, and similar fabrics. Flax has a wide range of growth, especially in temperate regions; it flourishes in the British Islands, and accommodates itself to a variety of soils, a mixture of sand and clay being the best. It forms an important part of the agriculture of Ireland, reclaimed bog-land furnishing good crops. It occupies the ground only a short time, namely, from April to July, so that another crop can be taken from the soil during the same season. The seed for sowing is usually of foreign growth, that of Riga being preferred, but the soil and climate of Egypt appear particularly suitable to this crop, and a large amount of our imports of late years have been from that country. The seed is first sorted into seed for sowing, and seed for crushing out the oil. The quantity sown per acre varies, but it is found that thin sowing promotes a coarse growth of the plants, while thick sowing produces tall and slender stems of fine fibre. When the young plants have risen to the height of two or three inches, they are carefully weeded by women or children, who creep along upon their hands and knees, with their faces to the wind. This is found not to crush the plants so much as if they went on their feet, and, on a breezy day, the wind will raise the plants to their former position. In June, the delicate blue blossoms open, and flax is then one of the most beautiful of crops. In some cases to prevent the crop from being laid by the wind, stakes are driven into the ground at regular intervals, and small ropes tied to them, as shown in fig. 38. When the seed bolls appear, and before the seed is quite ripe, the flax must be pulled: if left until the seed is ready to drop, the plant dies, its juices become exhausted, and the fibre loses its silky and elastic character. The pulling is carefully done by small handfuls at a time, and these are laid across each other to dry; after which they are collected into bundles, and arranged as in fig. 39, with the root ends on the ground.

In order to separate the woody portion of the stem from the fibre, the plant is steeped in water, but, if the seed is sufficiently ripe to be separated, it is done by passing the upper ends between the teeth of a comb, or *ripple* as it is called, consisting of smooth round iron teeth standing about twelve inches out of a block of wood, and fastened down to a long stool, where two men, seated one on each side, alternately draw a handful of flax between the teeth of the comb, as shown in fig. 40. Then comes the steeping or *retting* as it is called, for which purpose the flax is placed in ponds of soft water, or in a slow-flowing river, with stones to sink it beneath the surface, and a covering of straw to shade off the light. In the course of from eight to twelve days, during which the plant has been fermenting, the woody portion is sufficiently retted or rotted to separate easily from the fibre. The flax is therefore taken out of the water, and placed on the banks to drain, after which it is spread out on the land to dry. Retting produces a very unpleasant and unwholesome odour in the neighbourhood, and imparts a noxious quality to the water. Instead of *water-retting*, or steeping the flax in a pond, *dew-retting* is adopted, where the flax is exposed to the influence of dews and rain; this requires a longer time than the former operation, hence, *mixed retting* is sometimes adopted, where the flax is macerated in water, and the retting is finished in the air. A still better method of retting is by means of steam, for which purpose the flax is steeped in large circular vats, and the temperature is raised by a steam pipe to about 90° Fahr. In the course of a few hours fermentation sets in, and the decomposition of the resinous or gummy matter of the stalk proceeds rapidly. After about sixty hours the decomposition is complete, and the flax may be taken out and dried either in the open air or by artificial means. In some cases, the vat-retting is assisted by an alkaline solution. The cultivation of flax, including the retting, is such a delicate operation, that, according to its greater or less success, the price of the fibre may vary from 40*l.* to 80*l.* per ton.

When the flax is dry it is bruised, in order to separate the woody parts. Various implements are employed for the purpose, among which is the *brake* (fig. 41). This consists of two wooden frames, attached to each other by a hinge, furnished with bars, those of the upper frame fitting into the spaces of the bars in the lower frame. The upper set of bars may be brought down upon the lower set by means of a treadle, on releasing the pressure from which, a spring attached to the upper frame separates the two. It is by a repeated action of this kind that the woody portions of the flax are bruised and separated from the fibre, an object which is now also accomplished by means of rollers.

The next operation is *scutching*, which still further cleans the fibre. The *scutching frame* (fig. 42) is a board, set upright in a block of wood, with a slit cut out of the side. The bruised flax is held in the left hand and inserted in the slit so as to project from it; here it is repeatedly struck with a flat sword or *scutcher* (fig. 43), the blows being directed close to the slit, through which the flax is gradually drawn, by which means the woody portion or *boon*, as it is called, is got rid of. The cleaning of flax is sometimes accomplished by machinery, fluted cylinders being employed for breaking, arms or beaters projected from a horizontal axle for scutching, while revolving brushes complete the cleaning, and greatly improve the appearance of the flax. The *brushing machine* (fig. 44) is sometimes used at this stage.

When the flax arrives at the mill in order to be spun into linen yarn, the first operation is to divide it into lengths, the necessity for which will be understood when it is considered that flax varies in length from 26 to 36 inches, and that the part nearest the root is coarse and strong, the middle part fine and strong, and the upper part finer but not so strong. In some cases flax is divided into four parts, which are named respectively *middles*, *ends*, and *middle* and *end-middles*. The flax must not be divided by cutting but by tearing, so that the rough or ragged ends may twist together into an equal thickness. The *dividing machine* (fig. 45) consists of upright wheels for holding the flax, and a centre wheel furnished with oval teeth for dividing it; the centre wheel moves with great speed, while the outer or holding-wheels move slowly, so that the dividing wheel has time to perform its work before the handful of flax which the boy puts in has time to escape from the pressure of the holding-wheels.

The filaments of flax thus divided are next cleaned, split into finer fibrils, and arranged in parallel order by a process called *heckling*. At the same time the short fibres, which form *tow*,

which are unfit for spinning, together with dust and dirt, are removed. The *heckle* is a comb of iron or steel teeth, sharply pointed, let into a brass or iron plate, and attached to a block of wood. Heckles are of various degrees of fineness, according to the degree of fineness required in the *line*, as the flax fibre is now called. In using the heckle, the workman takes a *strick*, or lock of flax, by the middle, throws it upon the points, and draws it towards him. By repeating this operation many times, with different heckles, the tow is separated and the line prepared for spinning.

Heckling is often performed by machinery, for which purpose a quantity of flax is spread out, and fixed in an iron vice or holder (fig. 46). A number of these being filled, they are hooked on to a revolving drum (fig. 47), so as to allow one set of projecting ends in each holder to fall upon an internal drum, which is covered with sharp heckling teeth, and made to revolve with considerable speed in a direction contrary to that of the external drum. When the holders have travelled a certain way upon the outer drum, they are thrown off upon a rail, whence they are removed to a second heckling machine, when the other side of the strick is heckled. They may even be made to pass through a third machine, where the teeth are set finer on the drum. The holders are then opened, and the stricks are re-arranged, so as to allow those parts of the fibres to be acted on which had previously escaped the points. The brushing machine (fig. 44) is arranged somewhat on the plan of the heckling machine; but its inventor does not divide the flax into so many lengths as is usual, nor does he make so free a use of the heckling points.

The line now consists of long, fine, soft, glistening fibres, of a bright silver-grey or yellowish colour. As the tow collects among the heckle points, it is removed from them by means of brushes attached to wooden cylinders. The tow, being similar to cotton in its fibre, is somewhat similarly treated: it is transferred from the brushes to a revolving drum covered with cards as in fig. 15, from which it is removed by a crank and comb, as in fig. 16: it is then carded a second time, and is reproduced as a continuous sliver (fig. 17). This is transferred to the drawing-frames (figs. 20, 21, 22), and is extended by means of rollers in the usual way, the parallelism of the fibres being assisted by heckling points. The slivers are next formed into rovings, wound upon bobbins, and spun into a fine, but not very strong thread.

An improved form of *Tow Carding Engine* is shown in fig. 48. In this engine, the tow is passed round the carding cylinders, and is removed by three separate doffers, arranged at different distances, so as to take off three distinct qualities of tow. These are formed into slivers, and are led off at the side of the machine, where they are deposited in cans for the drawing-frame.

A few years ago, a proposal was made to convert flax into a cotton-like substance, by steeping it in a solution of carbonate of soda, and then adding a dilute solution of sulphuric acid. The hollow cylinders of the fibres becoming charged with the acid solution, carbonic acid gas is instantly generated within them, the expansive force of which splits up the fibres into a vast number of riband-like filaments, which considerably resemble raw cotton. This *flax cotton*, as it is called, admits of being treated in the same manner as cotton.

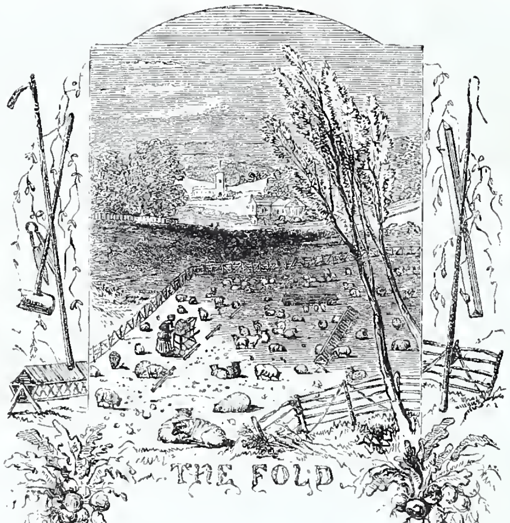
We now return to the heckled flax or line. The operations preparatory to spinning are spreading, drawing, and roving. The line is first placed upon the feeding-cloth of a *spreading-frame* (fig. 49), in such a way that the ends of one strick may reach to the middle of the next. The flax is then passed between a pair of rollers, which deliver it through heckling points to another pair of rollers, and these, moving much more quickly than the first pair, increase the length and diminish the thickness of the line, and form it into a flat narrow riband or sliver, which is deposited in a tin can. The slivers are transferred to a drawing-frame, where a number of them are drawn out repeatedly, as in the case of cotton, and they receive a slight degree of twist at the roving-frame, where they are wound upon bobbins, preparatory to spinning.

The flax spinning-wheel (fig. 52) has been, for the most part, superseded by those vast collections of machinery, which present so impressive a spectacle in the interior of a flax-mill. Still, however, the delicate manipulations of the hand have not been altogether superseded by the coarser but more productive results of the machine. Among the prizes awarded by the Jury (Class XIV.) of the Great Exhibition of 1851, was the sum of ten pounds to Ann Harvey, of Belfast, for perfection in quality of hand-spun flax yarn; a similar prize to a little girl ten years of age, belonging to the Heepen Spinning School, Bielefeld, Germany; and a similar prize to Jane Magill, of Belfast, 84 years of age, for the finest hand-spun yarn. We must, however, turn from the spectacle of youth and age competing together with equal success, and conclude this notice with a few words on machine-spun flax yarn.

The spinning of flax resembles the throstle-spinning of cotton, with the additional fact that the flax fibres require to be wetted in order to make them adhere to each other, and to render them more pliable and easy to twist. The spinster at the domestic wheel is accustomed to moisten the fibres with her lips; in the factory, water of the temperature of about 120° is contained in a trough which runs the whole length of the spinning-frame; the rapid motion of the spindle causes a dewy spray to be constantly thrown off, and gives to the air of the room a hot, steaming effect. The yarn is made into linen thread, by doubling, which thread, after having been bleached, is formed into balls or wound upon reels. The yarn itself is also wound upon reels, and then made up into *leas*, *hanks*, *bundles*, and *bunches*. Thus 300 yards of thread form one lea, 3,000 yards one hank, 60,000 yards one bundle, and three bundles make one bunch. The size or fineness of linen yarn is reckoned by the number of leas to the pound weight. From 300 to 400 leas is reckoned fine spinning; but the old woman of 84 years of age already noticed produced 760 leas. Ann Harvey's was about 600 leas.

Fig. 50 represents the interior of one of Messrs. Marshall's flax-mills in the neighbourhood of Leeds. It consists of one magnificent room on the ground floor, 396 feet long by 216 feet wide, presenting an area of nearly two acres. In this noble room, the machinery is arranged in parallel lines along the length, with spaces between and among them for the attendants. The room is lighted from the roof, which is formed of brick-groined arches, 66 in number, supported by iron pillars, with a conical skylight in the centre of each arch. Under the floor of this room are the shafts for imparting motion to the machinery, together with gas and water pipes, carpenters' shops and warehouses, hot and cold baths for the use of the operatives, &c. On ascending to the roof of this 2-acre room, the visitor is surprised to find himself in a grass field (fig. 51) with sheep feeding, and the conical skylights rising like so many glass tents or green houses. The use of the grass on this extensive roof is to prevent the sun from acting on the mixture of coal tar and lime, which forms the covering to the roof. Over this a layer of earth, eight inches thick, supports the grass. The mode of draining this roof is by making the iron pillars, which support it, hollow pipes, so that the rain water readily passes down them to be disposed of below. The upper extremity of each pipe is covered with a grating, to prevent the channel from being stopped up.

53. THE SOUTHDOWN SHEEP.



54

55. THE ARGALIS.

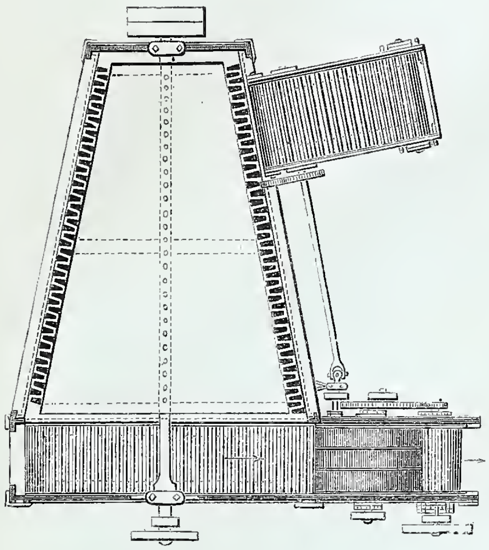
56. SHEEP WASHING.

58. SHEEP SHEARING.

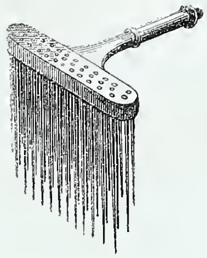
57. HIGHLAND FLOCK.

59. SHEEP IN WINTER.

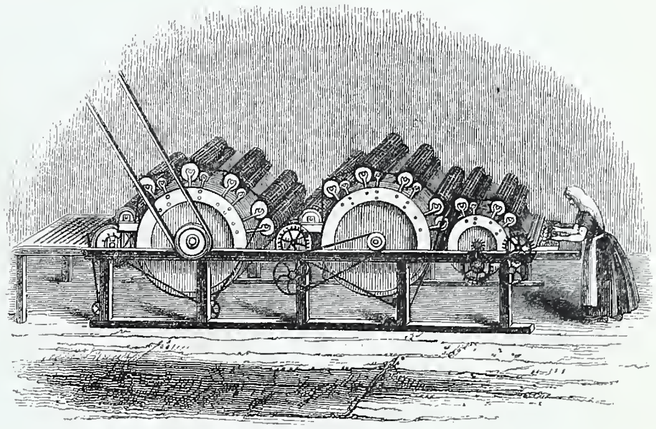
60. SCENE OF THE FIRST WOOL-GROWING EXPERIMENT IN AUSTRALIA.



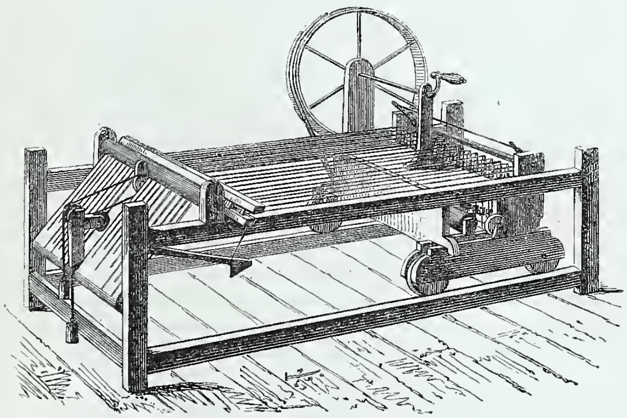
61 THE WILLY.



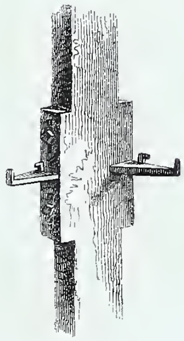
65. LONG WOOL-COMB.



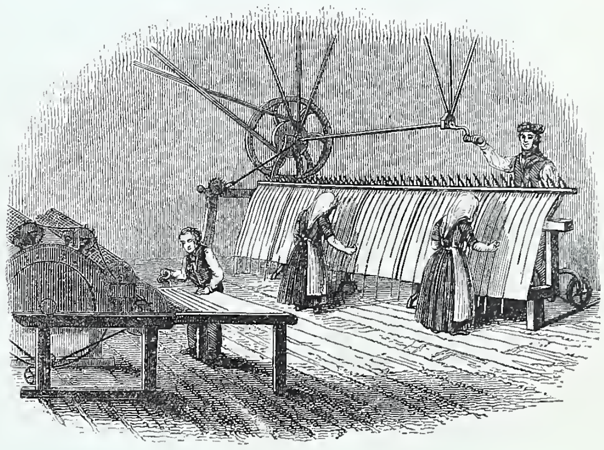
62. WOOL-CARDING ENGINE.



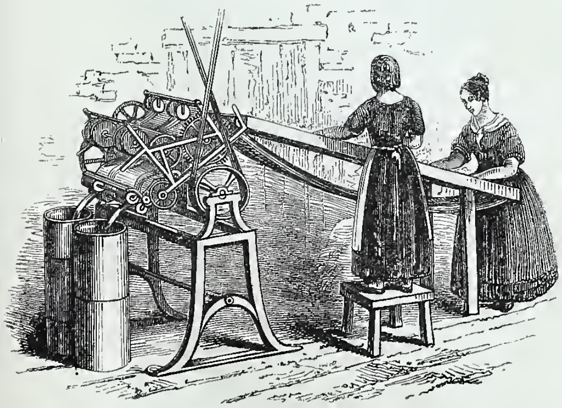
63. THE SLUBBING BILLY.



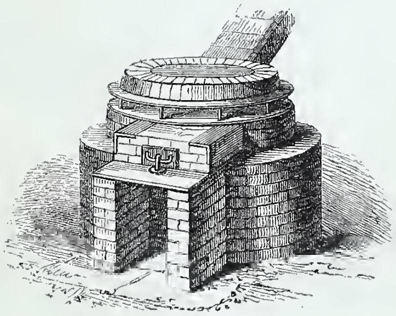
66. COMB-POST.



64. MODERN SLUBBING MACHINE.



68. BREAKING FRAME.



67. THE COMB POT.

69. DRAWING FRAME (8 INTO 1).

III.—WOOL.

The woolly covering of the sheep furnishes an excellent material for various kinds of clothing; and, accordingly, we find in most countries where this animal is pastured, that the spinsters of every family are, or have been, more or less occupied with it. It is remarked that King Edward the Elder, in order to give his children a proper princely education, "set his sons to school and his daughters to *wool-work;*" not the production of absurd pictures in a material which does not admit of pictorial effect, but the spinning of woollen fibres into yarn, and afterwards weaving them into some kind of cloth. At a later period, the art of spinning and weaving wool rose from a domestic to a national employment; and to mark its importance and the estimation in which it was justly held, the seat assigned to the highest law officer of the crown in the House of Lords was a woolsack, which it continues to be to this day.

The Domestic Sheep (fig. 53) is supposed to have descended from the *Argali* (fig. 55), which is still found wild on the mountains of Siberia and Kamtschatka. It resembles the *Mouflon,* or wild sheep of the mountains of Sardinia, Corsica, and Asia Minor. By cultivation, it gradually loses its horns, and exchanges a hairy for a woolly coat.

Wool is a peculiar modification of hair. When viewed under the microscope, it presents a number of oblique lines, as many as from 2,000 to 4,000 in the length of an inch, thereby indicating a scaly surface, which, together with its curved or twisted form, fit it for *felting,* on which so much of its value depends.

The woolly variety of hair forms the under-clothing of a large number of quadrupeds, although, in the greater proportion of them, it is concealed by the external coat of smooth, straight, coarse hair. In the wild sheep there is an excess of woolly hair; this admits of being modified and improved in various degrees by domestication, by choice of pasture and climate, and other means, until the original coarse wool is replaced by wool of different qualities, all of which are very superior to the original fleece, and admit of being grouped into two classes, namely, the *short* or *carding* wool, which is used in the manufacture of broadcloths, and *long* or *combing-wool,* which is used for worsteds. Each of these divisions contains a large variety of sorts, according to their fineness, the length and soundness of the staple, and other particulars. In the Great Exhibition, some choice wools from Austria excited the admiration of the trade, for their "substance in the staple, and fineness and elasticity of the component fibres, the spiral curves of which are close and regular, and are immediately resumed, after being obliterated by stretching the fibre,—the length of which is also considerable for wool of this *carding* quality, the most valuable for the finest descriptions of cloth."

The wool, in its natural state, is nourished by a secretion from the glands of the skin, known as the *yolk:* it also serves to mat together the fibres of the wool, and thus to form a defence for the animal against wet and cold. In some breeds, the yolk is equal to about half the fleece, and as it does not add to the value of the shorn fleece, it is usually washed out before shearing, in a running stream (fig. 56), the yolk being a true soap, and therefore soluble in water. If the yolk were left in the fleece after shearing, it would ferment, and impart a harsh quality to the wool. Wools are also known in commerce as *fleece* wools and *dead* wools, the first being obtained from the annual sheep-shearing (fig. 58), the latter from the dead animal. The best wools are generally those that are shorn towards the end of June or the beginning of July.

The celebrated *Merino* wool is obtained from the migratory sheep of Spain. Immense flocks of these sheep were conducted twice a year, namely, in April and October, a considerable journey to enable them to pass the summer in the mountains of the north, and the winter in the more southern plains. The excellence of the wool was supposed to be due to the equality of temperature preserved by these migrations. About the year 1765, the Merino was introduced into Saxony, and, after some years, became naturalised in that country. By this means, the Saxon breed was improved, and, in due time, the Saxon fleece was found to be superior to the Spanish. The Merino has also greatly improved the breeds of other countries, such as those of Sweden, Denmark, Prussia, &c. In Hungary, the flocks were, at one time, among the most wretched in Europe, the milk being the chief object, for the sake of the butter and cheese obtained from it. The introduction of the Merino, however, with increased care in the management of the flock, so far improved the native breed that the Hungarian fleece competed with that of Silesia and of Saxony, and has beaten the Spanish Merino in every market. The Merino has had less influence on the sheep of England, than on those of other countries, since the chief object of the English farmer is to fatten sheep for the market, and to regard the wool as a secondary product. The system of artificial feeding (figs. 54, 59) enables the farmer to send his sheep to market quickly; whereas if the wool be the object, the animal requires a long time to arrive at maturity, and the increased value of the wool cannot be set against the disadvantage of having the sheep longer on hand. Hence the plan has been, in this country, to purchase the finer foreign wool, and to rear our sheep for the sake of the mutton. The principal demand for English wools is for flannels and for coarse cloth, such as that used for coachmen's great coats.

The introduction of the sheep into Australia added greatly to the wealth of the colony. New South Wales had no sheep of its own, and a small flock was originally introduced from Bengal. These sheep are described as being more like goats, with a coarse and hairy fleece; but the climate agreed with them, and they improved, and still more so when the South Down (fig. 53) and Leicester varieties were added to the flock. In a short time, both the fleece and the carcase became doubled in value, and the introduction of the Merino still further improved the breed. It occurred to Captain (afterwards Lieutenant-Colonel) Macarthur that, if the fleece of the common Merino became finer and softer under the climate of New South Wales, it was not improbable that even the Saxony wool might be increased in value. He, therefore, imported some sheep direct from Germany, and found, after fairly testing the experiment, that if the Saxon fleece had not been improved, it was superior to any other in the colony. Fig. 60 is taken from a sketch of part of the Camden estate of Captain Macarthur. The success of these experiments has been complete. The first importation of wool from New South Wales in 1807 was 245 *lbs.*: in the year 1848, it amounted to 23,000,000 *lbs.* valued at upwards of 1,200,000*l.* The discovery of gold in Australia arrested for a time the progress of wool-growing, but it is probable that the amount of toil and expense required for securing the precious metal by direct means, will have satisfied industrious men, that the more indirect methods of agriculture and honest trade are as well, or even better calculated to make a man prosperous.

The two great divisions of wool into carding and combing give rise to two distinct branches of the woollen manufacture, namely, *cloth* and *worsted,* the last word being the name of a small town in Norfolk, where this class of goods was first made. Until about thirty years ago, worsted fabrics were made of wool alone, with the exception of bombazines, and some other mixtures; but in that year, goods, consisting of a worsted weft and a cotton warp, came into use. In 1836, the wool of the *Alpaca,* an animal of the Llama tribe, belonging to the mountain ranges of Peru, was introduced: this wool is of various shades of colour, is remarkably bright and lustrous, has great length of staple, and is

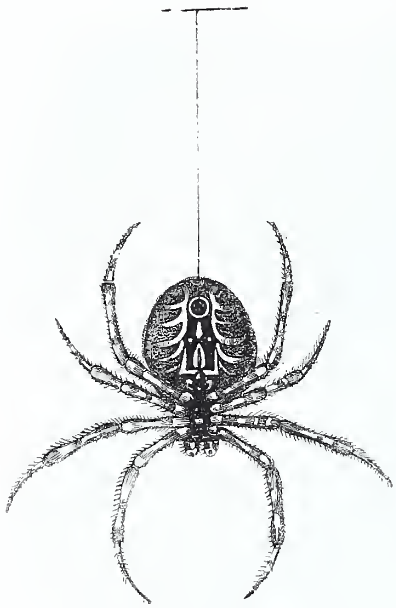
extremely soft. It soon acquired a high rank in the worsted trade. About the same time, *Mohair*, the wool of a goat from Asia Minor, came into use, and led to the production of many beautiful fabrics, while the combination of silk with these new materials led to further varieties in articles of clothing and furniture.

During the year ending 31st December, 1856, there were imported into the United Kingdom from British possessions out of Europe, 81,893,148 *lbs.* of sheep and lambs' wool; from other parts, 31,343,751 *lbs.* making a total of 113,236,899 *lbs.* Also, of wool of the Alpaca and Llama tribe, 2,974,493 *lbs.*

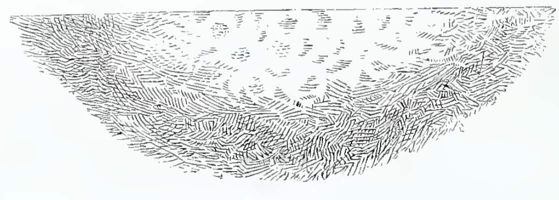
First, with respect to the manufacture of broad-cloth. The three varieties of wool most in request are the German, the Australian, and the Cape, while the wools of Odessa and New Zealand are also more or less in request. Wool arrives in England in its natural state, or in the *grease*, as it is called, with the yolk and dirt adhering. Or the wools may be *hand-washed*, where the sheep, previously to shearing, has been washed in a running stream. *Scoured wools* have been scoured and cleansed after the shearing.

The first operation at the factory is called *sorting*, or dividing the wool into qualities, such as *primes*, *seconds*, and *thirds*. This is done at a table formed of horizontal bars of wood, so that on opening the fleece and separating the qualities of wool, loose dirt, &c. may fall through. The wool may then be *scoured* or washed, to get rid of the animal grease; after which it may be dyed, or the dyeing may be left till the cloth is woven. In the one case the cloth is said to be *wool-dyed*, and in the other, *piece-dyed*. Supposing the wool to be dyed, it is passed through the *willy*, or *twilly*—resembling the *willow* of the cotton manufacture—(fig. 61), consisting of a large wooden cylinder or cone, furnished with iron spikes, enclosed in a wooden case, also furnished with spikes. The wool is supplied to this machine by an endless web, or feeding-cloth, and passing between feeding rollers, is exposed to the action of the spiked cylinder, which, revolving rapidly, tears apart the fibres and disperses the dust and dirt through a grating below. The wool is next picked, in order to remove seeds and foreign matters, or locks of wool which have not properly taken the dye, or which belong to other sorts. The wool is next spread out on a stone floor, and sprinkled with Gallipoli or palm oil; layer being piled upon layer after each oiling. The wool is again passed through the willy, in order to mix the oil and the wool thoroughly. The wool is now ready for the *scribbler*, which is similar in principle to the cotton-carding engine (figs. 15—19). Scribbling is, however, a coarser process than carding, and its object is to form the oiled wool into a broad thin fleece or lap. Wool goes through the scribbler two, three, or four times, so that the fibres may be well opened; after which it is carded. The object of the *wool-carding engine* (fig. 62) is not to place the fibres parallel, as in the case of cotton, but to open them and make them cross each other in all directions. The large cylinders, or *card-drums*, and the small cylinders, or *urchins*, all covered with carding wires, prepare the wool, and the last cylinder, or *doffer*, which is covered with straight parallel strips of wire, allows the doffing knife to remove the wool in the form of separate slivers, each the length of the doffing-cylinder, and these fall into the plates of a plated cylinder, called the *roller-bowl*, which being partly covered with a case or shell nearly in contact with it, the slivers are rolled into cardings, and are received upon an apron at the opposite end of the machine. The cardings have next to be twisted into yarn, for which purpose a machine, founded on the spinning-jenny (fig. 31), and called the *slubbing-billy* (fig. 63), was introduced. It consists of a wooden frame, within which is a carriage moving upon the lower side rails, and containing a number of spindles, which are made to whirl round by means of cords, passing round the pulley of each spindle and connected with a drum, which extends the whole breadth of the carriage, and to which motion is given by turning the handle of a large wheel, which is connected by a strap with the drum. The cardings are arranged upon a slanting apron at the end of the frame, and pass under a roller, called the *billy-roller*, which presses lightly upon them. In front of this roller is a movable rail, which, when it rests upon the cardings, prevents them from being drawn through, and when elevated prevents the cardings from being drawn forward by the retiring of the spindle-carriage. The twisting of these cardings and the winding them up on the spindles does not differ greatly from similar operations already described on the spinning-jenny. The cardings, as fast as they are produced at the carding-engine, are brought by children, and attached to the ends of the cardings resting on the sloping apron: this joining is performed by a slight lateral rolling motion of the fingers of the right hand. By the constant activity of the little pieceners, the cardings on the apron are always kept at the proper length. The slubbing-billy is now mostly superseded by the *slubbing-machine* (fig. 64), which does not greatly differ from the cotton-mule (fig. 32); but the operation of slubbing has been partially superseded by a machine called the *condenser*. The wool is now in the condition of yarn fit for weaving, and will be again noticed when we come to speak of that operation.

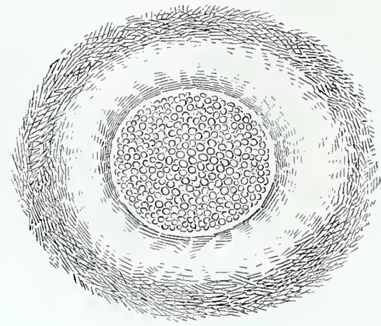
In the preparation of worsted yarn, care is taken to dispose all the fibres in parallel lines, as in the case of cotton and linen, and not, as we have seen in the case of short wool, to allow them to cross in various directions, to assist them in felting together in a subsequent process. The long wool is scoured, dried, and willowed, preparatory to *combing*, which is one of the distinguishing operations of long wool. The wool-comber is furnished with a couple of combs, one of which is shown in fig. 65, a *post* (fig. 66), to which it can be attached, and a small stove, called a *comb-pot* (fig. 67), for heating the teeth of the combs. The wool-comb consists of several rows of sharp steel teeth of different lengths, fixed to a wooden stock or head, covered with horn, from which proceeds a perforated handle, made to fit into certain projections in the upright post. The comb-pot is a flat iron plate, heated by means of fire or of steam, and above this is a similar plate, with sufficient space between the two to admit the teeth of the comb. The heated comb being attached to the post with the teeth upwards, the workman takes a handful of wool, sprinkles it with oil, rolls it up in his hands, and then throws one-half of it over the points of the comb; he draws it repeatedly through them, and leaves each time a few stray filaments in the comb. When the wool is thus disposed of on the comb, the latter is removed to the stove; an empty comb is taken therefrom, mounted on the post, and filled with wool as before. The man then takes both combs, sits down, and holds one of them on his knee with his left hand, and with the other comb in his right hand he introduces the teeth of one into those of the other, draws them through, and thus transfers all the wool to one comb. This process is repeated again and again, until the fibres are laid parallel. When the operation is complete, a quantity of short wool, called *noyl*, about one-eighth of the quantity employed, remains in the comb; this is transferred to the short-wool manufacture. The long wool, after leaving the comb, requires to be combed again at a lower temperature before it is fit for the spinner. Wool-combing is a laborious and unhealthy occupation, and is performed in some mills by self-acting machinery. The wool, as it is combed into slivers, is formed into narrow bundles, called *tops;* these being unrolled, the slivers are separated and thrown loosely over a pin, within reach of an attendant who, taking a sliver, spreads it flat upon a feeding-board or apron, presenting the end to the first pair of rollers of the *sliver-box*, or *breaking-frame* (fig. 68), which draw the sliver in. When it has passed half through, the end of another sliver is placed upon the middle of the first, and they are drawn through together. A third sliver is placed on the middle of the second, and in this way the short slivers are united and extended by other pairs of rollers into one long and uniform sliver, which is received into a can. A number of these are drawn into one at the drawing-frame (fig. 69); these are also received into cans, and afterwards pass through the operations of roving and spinning, which resemble in principle those operations as described under cotton.



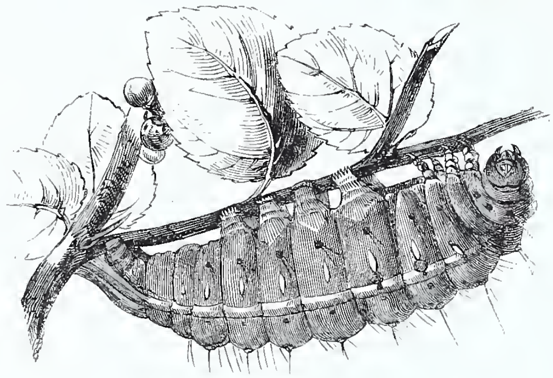
GARDEN SPIDER (*Natural size*).



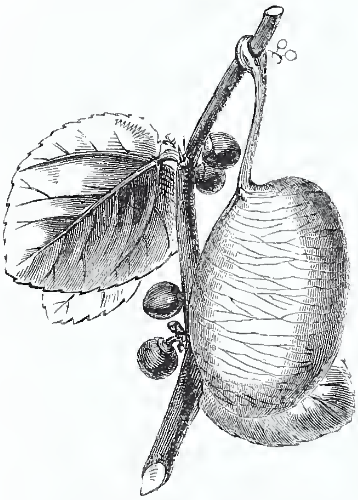
71. SPIDER'S NEST ATTACHED TO A FLAT SURFACE.



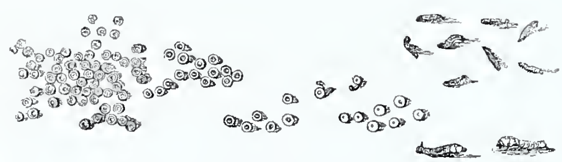
72. SPIDER'S NEST LAID OPEN.



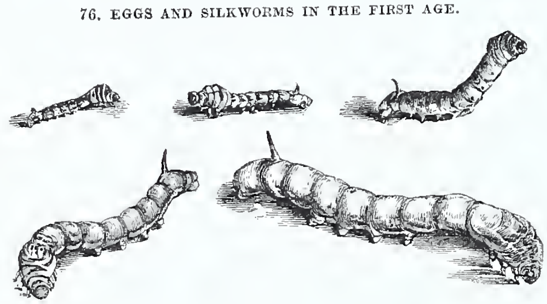
73. THE TUSSEH SILKWORM.



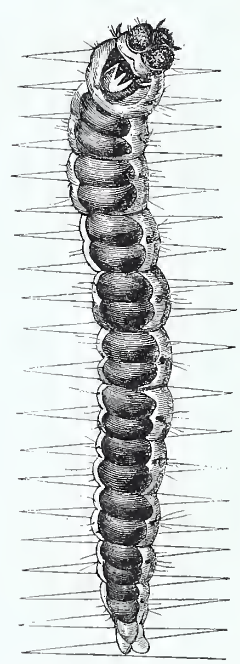
74. COCOON OF THE TUSSEH SILKWORM.



76. EGGS AND SILKWORMS IN THE FIRST AGE.

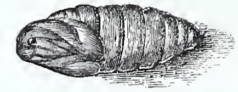


77. PROGRESSIVE GROWTH OF THE SILKWORM.



75. SILKEN LADDER SPUN BY THE GOAT-MOTH CATERPILLAR.

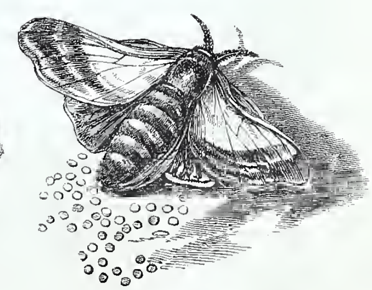
79. FULL-GROWN SILKWORM.



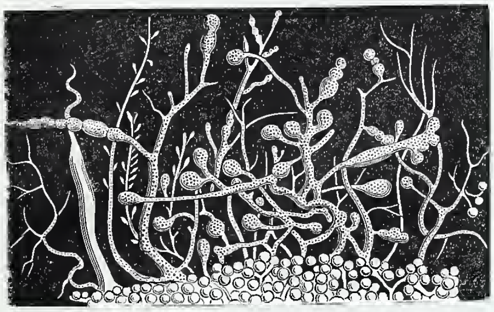
81. THE CHRYSALIS.

80. THE COCOON.
(*A portion of the floss silk has been removed.*)

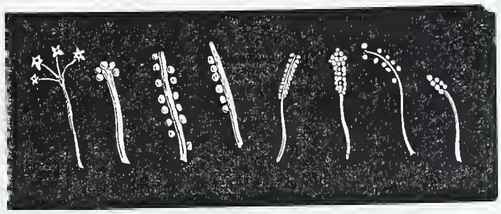
78. SILKWORM ON MULBERRY LEAF.



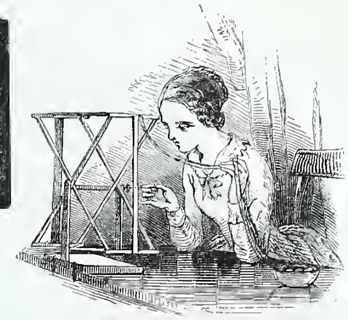
82. FEMALE SILKWORM MOTH AND EGGS.



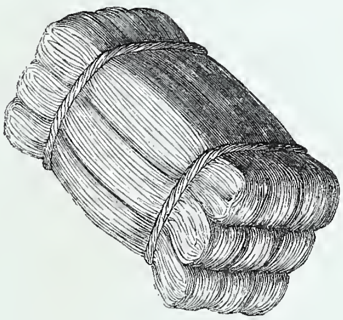
83. ADVANCED STAGE OF MUSCARDINE (*Highly magnified*).



84. EARLY STAGE OF MUSCARDINE (*Magnified*).

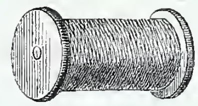


85. GIRL WINDING SILK.



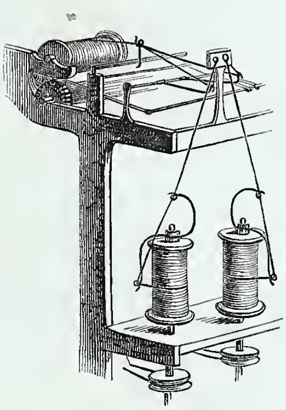
86. BOOK OF SILK FROM CHINA.

87. THE WHITE MULBERRY (*Morus alba*).

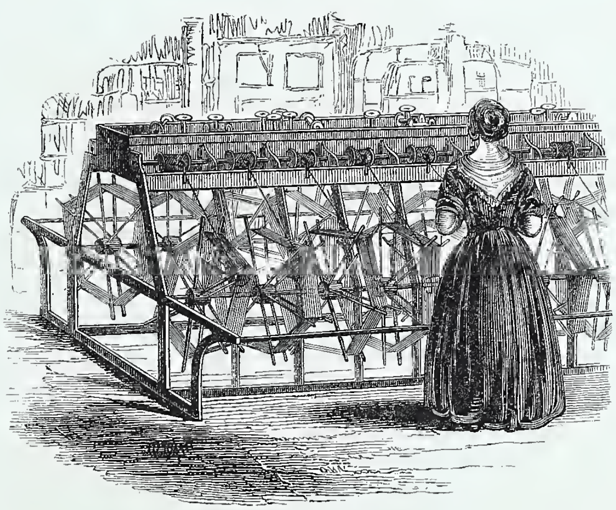


88. BOBBIN.

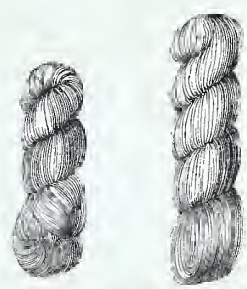
91. SLIP FROM BENGAL.



89. DOUBLING.

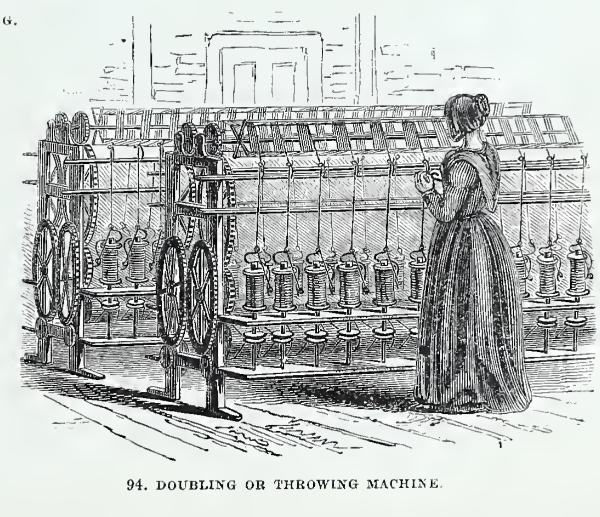


90. WINDING.



92. HANKS FROM ITALY.

93. SPINNING MACHINE.



94. DOUBLING OR THROWING MACHINE.

IV.—SILK.

There are few things more wonderful in nature or in art than the mighty results which are frequently brought about by small and apparently inadequate means. Nothing can appear more insignificant than a single polype; yet, by the united efforts of millions of polypes, vast reefs of solid rock rise up in the ocean, and form clusters of islands for man to inhabit. A caterpillar, spinning from its own intestines a structure which we may term either its cradle or its grave, may also appear an insignificant object; but, when we find myriads of these caterpillars encouraged and protected by many nations of the earth, their united labours lead to results of a very surprising character.

The Chinese are the most extensive cultivators of the silkworm. From their country, the culture spread to Japan, to Tonquin, to Siam, to Hindostan, to Persia, to Greece, to Italy, and to France. We obtain supplies of silk from all these countries except Tonquin and France, the latter country consuming all that it produces. The climate of Great Britain is not adapted to the successful culture of the silkworm, nor do we receive any silk from our colonies. China affords the great supply, and this has gone on increasing. In 1830, we received 4,842 bales, and in 1857, we imported 94,612 bales from China—an increase of nearly twenty-fold. The cost of the last-named import was about 12,000,000*l.* sterling, or more than double the value of our imports in tea. There are several reasons for this prodigious increase. In 1830, our intercourse with China was through the East India Company, and our trade was restricted to a single port. Since that time, the trade has been made free, and four additional Chinese ports have been opened to us. Besides this, a murrain had attacked the silkworms of Europe, which led to increased imports from China. The production of Indian silk is limited to a few districts of Bengal Proper, and the supply is very scanty, amounting last year to no more than 9,011 bales. The quantity from Turkey and Persia is also very small. The silk of Persia is inferior in value to that of China, by as much as 30 per cent. The silk of the North of Italy is 60 per cent. better than that of China, and still more valuable than that of the average of British Bengal. The production of any raw material which requires skill and care in the preparation, may be taken as a test of civilisation; and, measured by such test, Turkey and Persia are at the bottom of the scale, Bengal comes next, China next, Italy next, and France, notwithstanding the disadvantages of climate, probably takes rank above Italy.

The insect which furnishes the most ready and available supply of silk is the caterpillar of the mulberry-tree moth (*Bombyx mori*), fig. 82, belonging to the tribe of mealy-winged nocturnal insects. The production of silk, however, is by no means confined to this insect: it is a common working material in the insect world, as well as a weapon of offence and defence. Thus, the garden spider (fig. 70) makes its web of this material; and when its labours for the season are over, deposits its eggs in a warm silken bag (fig. 72), which it attaches to a flat surface (fig. 71) in some sheltered place, where it remains throughout the winter; the warmth of the following spring being sufficient to hatch the eggs. As the spiders, like other insects, let themselves down by a silken line, so they ascend by means of the same material, often in a very ingenious manner, as in fig. 75, where a goat-moth caterpillar having been put into a glass tumbler, escaped therefrom by means of a silken ladder, as shown in the figure. In Bengal, the nests or cocoons of the *Tusseh* silkworm (figs. 73, 74) furnish a large supply of coarse, dark-coloured silk, which is woven into a cheap durable cloth. When the larvæ are near their full size, they are too heavy to crawl in search of their food with the back upwards, as is usual with most caterpillars; but traverse the small branches, suspended by the feet. The cocoon is of an oval shape, attached to a branch by a thick, strong, silken cord. The *Arindy* silkworm, also a native of Bengal, produces an abundant supply of delicate, glossy silk, which does not admit of being unwound from the cocoons, and is, therefore, combed, carded, and spun like cotton: the thread is woven into a coarse kind of white cloth, of so durable a texture, that a person can scarcely in his lifetime wear out a garment made of it. There are silk-producing insects in other parts of the world, which furnish local supplies of silk. In some parts of South America, cocoons of grey silk, eight inches in length, have been described; but none of these insects yield a silk which combines so many valuable properties as the ordinary silkworm.

The eggs of the silkworm moth (fig. 76) are smaller than grains of mustard seed: they are slightly flattened; and are at first of a yellowish colour, but change in a few days to a slate-colour. In temperate climates, they are kept through the winter until the mulberry-tree puts forth its leaves in the spring. The white-fruited mulberry-tree (*Morus alba*), fig. 87, a native of China, is the proper food for this insect; and it is remarkable that, while other trees nourish innumerable tribes of insects, the mulberry-tree is seldom attacked by any but this one insect. The worms, when first hatched, are about a quarter of an inch long, and of a dark colour (fig. 76): they must be fed on young and tender leaves, and if their food be properly supplied, they will remain contentedly upon it, and manifest no roving propensities. In the course of eight days, the creature rapidly increases in size, so that its skin has become too small for its body: it now remains three days without food, during which a secretion forms under the skin—on the surface of the new skin, in fact; and this enables the caterpillar to cast off the old one. But it also assists itself in this object by means of silken lines, which it attaches to adjacent objects. These hold the old skin tightly, and the animal creeps out of it; the whole of the covering of the body, including that of the feet and of the jaws, being cast off. The moulted worm is of a pale colour and wrinkled: it now recovers its appetite, and grows so rapidly that the new skin is filled out, and, in the course of five days, another moult is required. Four of these moults and renewals of the skin bring the caterpillar to its full size (see figs. 77, 78, 79), when it is nearly three inches long, and consists of twelve membranous rings, which contract and elongate with the motion of the body. There are eight pairs of legs, the first three pairs being covered with a shelly or scaly substance, which also invests the head. The mandibles are strong and are indented like a saw, and are in constant use at this time, the appetite of the animal being voracious. Beneath the jaw are two small orifices through which the insect draws its silken lines. The silk is a yellow transparent gum, secreted in slender vessels, and wound, as it were, upon a couple of spindles within the stomach; which vessels, if unfolded, would measure ten inches in length. Along the sides of the body are nine pairs of spiracles or breathing holes: near the mouth are seven small eyes, but the two spots higher up, which so much resemble eyes (fig. 79), are only portions of the skull. When at maturity, the caterpillar is of a rich golden hue: it then leaves off eating and selects a corner in which to spin its cocoon. It first forms a loose structure of floss-silk, and within it the closer texture of its nest of an oval shape (fig. 80): the caterpillar remains working within it until it gradually disappears; it takes no food, but, constantly spinning its beautiful winding-sheet, its body diminishes one-half, and the cocoon being complete, it once more changes its skin and becomes transformed into an apparently lifeless chrysalis or aurelia (fig. 81), with a smooth brown skin, and pointed at one end. It remains in this state for two or three

weeks, and then emerges in the form of a perfect winged insect, the silk-moth (fig. 82). In order to escape from the cocoon, it moistens the interior with a liquid which dissolves the gum that holds the fibres together, and, pushing them aside, escapes. The perfect insect has but a short life, and only one object to accomplish; namely, to provide for the continuation of the species. She lays her eggs in the course of two or three days, and then dies.

The silkworm is a delicate insect, and requires careful nursing; it is liable to many diseases, among which is one characterised by the formation of a minute cryptogamous plant or mildew within the body of the living insect. When it is exposed to damp and fermenting food and litter, there forms in the fatty matter of its body a number of sporules, supported by minute stems, specimens of which, highly magnified, are represented in fig. 84. These increase to such an extent that the vegetation pierces the skin, and imparts a general mealy character to the body (fig. 83); it soon ripens its seed, which floats in the air to every part of the nursery, inoculating the healthy worms; the first patient soon dies, and its dead body continues to be a source of contagion. The disease is called *muscardine* in France, from the name of a sugar-plum, which it somewhat resembles. The Italians name it *calcinetto*, from the chalky or mealy appearance of the skin. A solution of blue vitriol applied to the woodwork, frames, &c. of the nursery, is useful in destroying the seeds of the fungus; but the best preservatives are rigid cleanliness, and attention to ventilation. The Government of France have, at different times, offered premiums for the best modes of curing and preventing disease in the silkworms; and, at the time we are writing, the Austrian Government has placed a large sum of money at the disposal of the Central Sericultural Society of Italy with a similar object. Some idea of the extent of the silk-growing operations in France may be formed from the fact that, in the department of the Drôme, upwards of 3,000,000 mulberry-trees are required to supply the food of the worms.

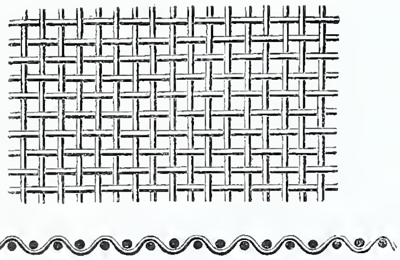
When the crop of cocoons is gathered in, about one-sixtieth part is set aside for the production of eggs, the finest cocoons being selected for the purpose. The female cocoons are heavier and rounder than the male, and a due proportion of each sort is taken: they are preserved in a dry room. The main crop of cocoons is next sorted according to their qualities, the vitality of the enclosed chrysalis is destroyed by heat, floss silk is removed, and the cocoons, being immersed in warm water to soften the gum, a number of the loose ends are twisted together, passed through a metal loop, which rubs off dirt and impurities, and is then passed on to the reel, which has a shifting side motion, so that the thread of one revolution may not overlay that of another; for, if allowed to do so, they would be glued together before the gum had time to harden in the air. When a single filament breaks or comes to an end, its place is supplied by a new one, that the united thread may be of equal thickness. The cocoons are not entirely wound off, but the husk containing the chrysalis is added to the floss silk under the name of *waste*. Eleven or twelve pounds of cocoons yield one pound of silk, from 200 to 250 cocoons weighing one pound, so that not less than 2,817 are required for a pound of silk. This estimate refers to the ordinary cocoon, which is of a bright yellow colour. Major Bronski, of Bordeaux, has succeeded, under improved cultivation on a plan of his own, in obtaining a race of silkworms not subject to disease, producing large and equal-sized cocoons of a pure *white* colour, the silk of which is equal in all its length, strong and lustrous, and of an average length of 1,154 yards.

The reeled silk is made up into hanks, the forms of which, as well as the qualities, differ in various countries, as will be seen from the figures 86, 91, and 92. When the raw silk reaches the factory, it passes through a number of processes which vary with its ultimate destination. It is *wound* and *cleaned* for weaving into Bandana handkerchiefs, and is further *bleached* for gauze and similar fabrics. With this amount of preparation it is called *dumb singles;* but when wound, cleaned, and *thrown*, it is called *thrown singles*, and is used for ribbons and common silks. If wound, cleaned, doubled, and thrown, and *twisted* in one direction, it becomes *tram*, and forms the woof or shoot of *gros de Naples*, velvets, and flowered silks. If wound, cleaned, spun, doubled, and thrown, so as to resemble the strand of a rope, it is called *organzine*, and is used for warp. When the natural gum of the silk is left in it, it is called *hard;* but if removed by *scouring*, it becomes *soft*.

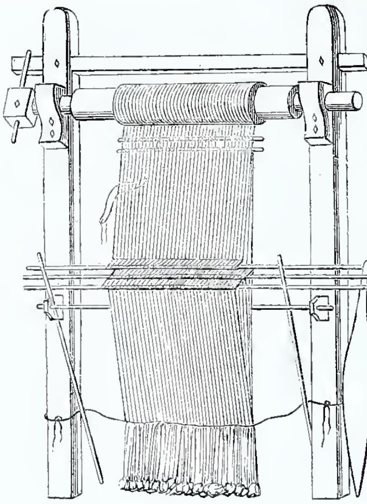
The first operation is to open the hanks, and stretch them upon light six-sided reels of lance wood, called *swifts* (fig. 90), from which they are transferred to bobbins, arrangements being made to wind the filament upon them in a spiral or oblique direction, to prevent lateral adhesion (fig. 88). The bobbins thus filled are removed to a *cleaning* or *picking* machine, where the filament from each bobbin is passed over a glass or iron guide-rod, and then drawn through a brush or cleaner, in order to separate impurities. Each filament is dragged from its bobbin through the cleaner to another bobbin, and, should a knot or a mote occur, the filament is prevented from passing through a bar of metal, which bar becomes depressed, and the bobbin is thereby lifted off the friction roller, from which it receives motion; the attendant, noticing this, removes the impediment, and again sets the bobbin in motion. The next process is *spinning*, not the twisting together of short fibres as in the case of cotton, flax, or wool, but of the continuous filament of clean silk. The spinning is accomplished by means of the bobbin and fly (fig. 93). Where a number of filaments are twisted together, the process is called *doubling* or *throwing*, which last term appears to have been derived from the rope-maker, who *throws* twists into his rope. In doubling, the silk filaments are arranged parallel on a horizontal wheel, and passed through the eye or loop of a rotating fly (fig. 94), by the rotation of which a number of filaments are twisted together. The twist varies according to the uses intended. In spinning single filaments, the twist is to the right; for tram, the filaments are doubled and then twisted to the right; for organzine, the filament is twisted to the left, then doubled and twisted to the right, and so on, the texture of various woven fabrics depending on these variations.

Fig. 89 represents a contrivance in the doubling frame for stopping the bobbin, should one of the filaments break. If two threads are to be doubled, each thread is passed under the hook of a wire which it supports, and, should the thread break, the wire falls down on a lever, which it depresses, and its opposite end arrests the motion of a bobbin.

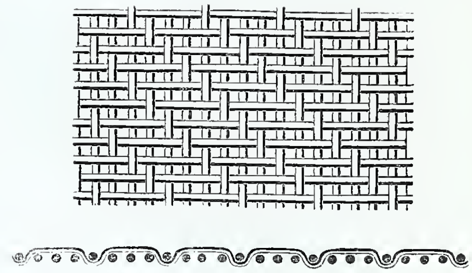
Some of the heavier descriptions of silk thread, such as sewing or fringing thread, are prepared at a throstle frame, similar to that used for cotton (see fig. 29); the floss silk, and the refuse of throwing, are worked into yarns for cheap shawls and handkerchiefs. The waste is sent to the spinner in small balls, which are sorted, heckled, cut up into short lengths, purified by boiling, and, lastly, carded and formed into yarn by processes similar to those adopted for cotton, or, instead of cutting up the waste, it may be drawn into slivers, by a modification of the machinery used for flax.



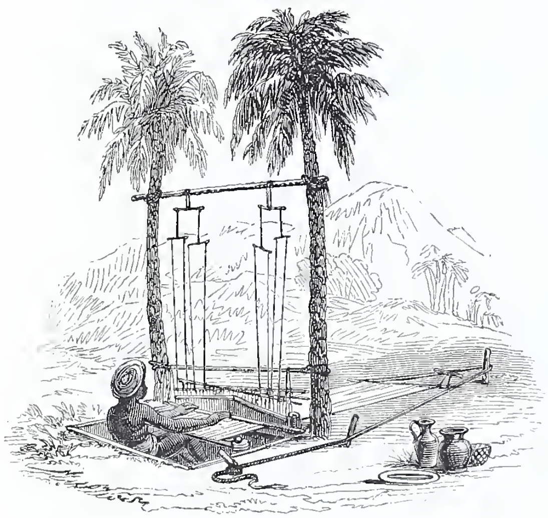
95. PLAIN WEAVING.



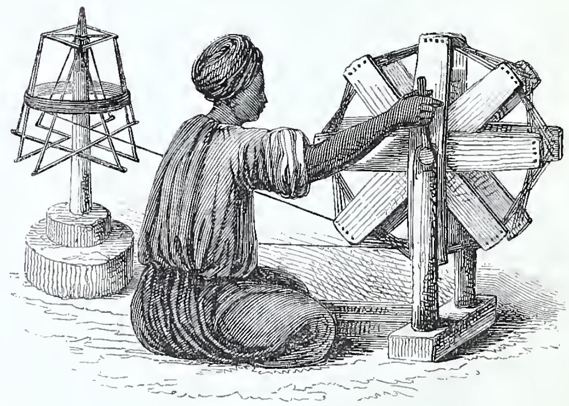
97. ANCIENT LOOM.



96. TWILLED WEAVING.

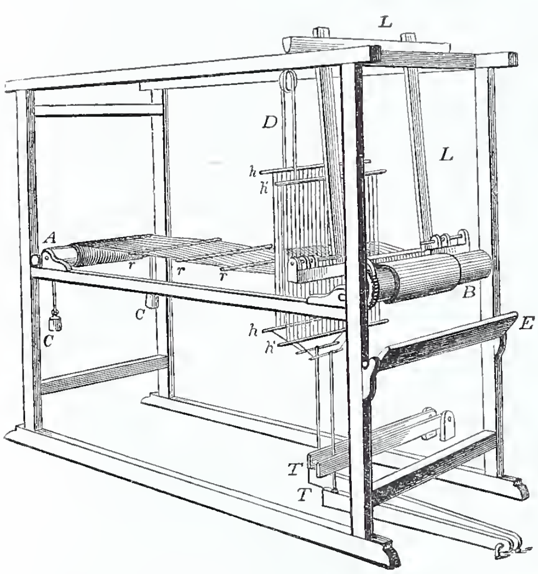


98. HINDU WEAVER.

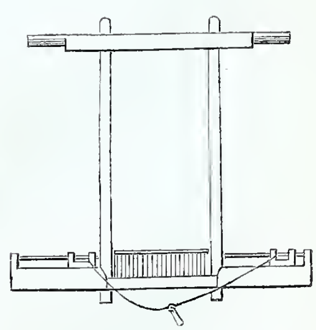


100. ORIENTAL WEAVING.

99. MODERN EGYPTIAN WEAVER.

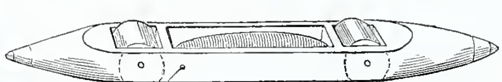


101. THE COMMON LOOM.



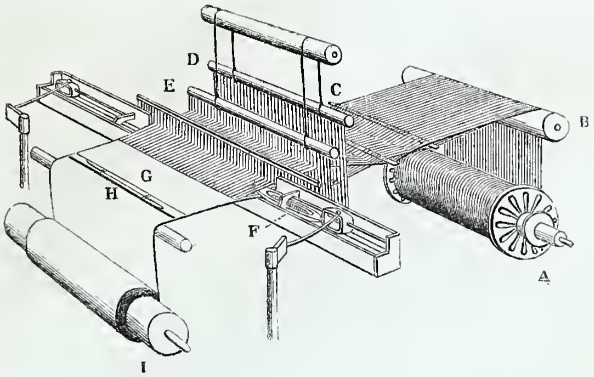
102. BATTEN, REED, AND SHUTTLE-RACE.

105. TEMPLES.

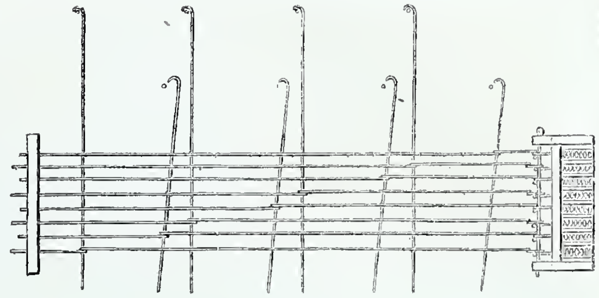


103. THE SHUTTLE.

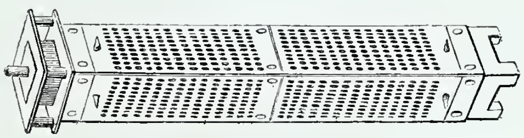
104. THE FLY-SHUTTLE.



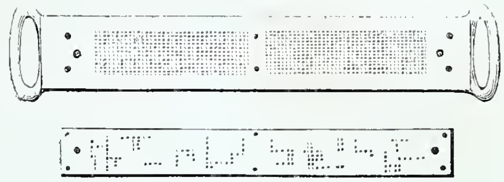
106. PRINCIPAL PARTS OF A POWER-LOOM



107. PRINCIPLE OF THE JACQUARD APPARATUS.



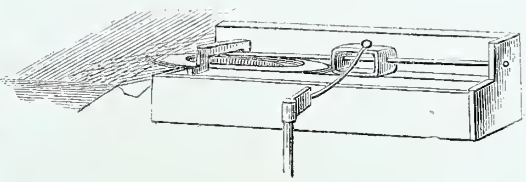
108. JACQUARD DRUM.



109. PERFORATED PLATE AND CARD.

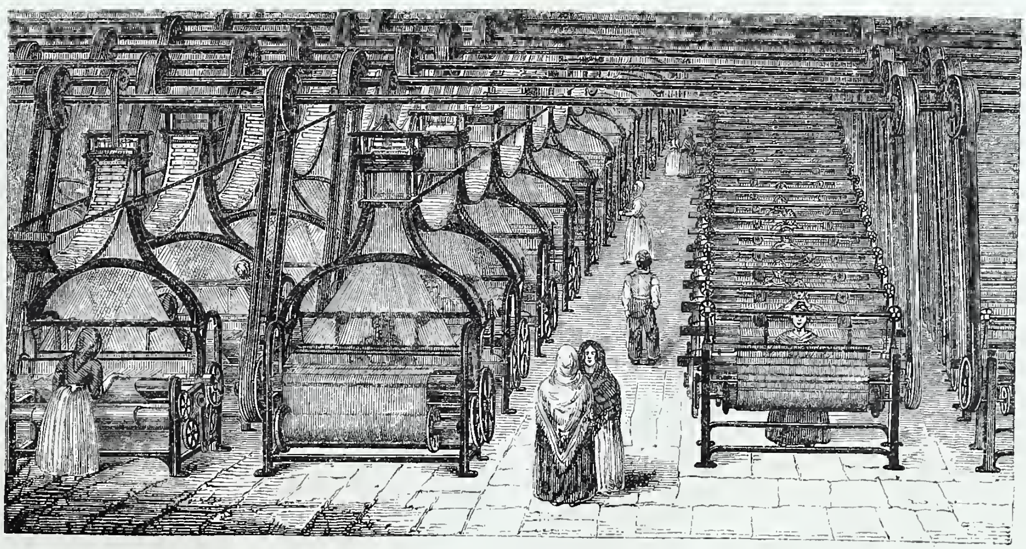
110. JACQUARD NEEDLE.

111. JACQUARD CARD MAKING MACHINE.



112. THE SHED.

113. POWER-LOOM.—(*Cotton.*)



114. ACKROYD'S LOOM-SHED AT HALIFAX.—(*Worsted Goods.*)

V.—WEAVING.

Weaving is one of the most ancient of arts: it is mentioned by Moses (Exod. xxxv. 35) as one of the arts taught by those whom the Almighty had filled with wisdom of heart, "to work all manner of work, of the embroiderer in blue, and in purple, in scarlet, and in fine linen, and of the weaver." The fine linen of ancient Egypt deserved its high character, as we know from the best judges of the present day, who have had opportunities of inspecting it in the mummy cloths which have been so curiously preserved during several thousand years. It is described as being close and firm, yet very elastic; and the yarn, both of the warp and of the woof, remarkably even and well spun. In one specimen the thread of the warp was double, consisting of two fine threads twisted together; the woof was single. In other specimens the warp had three, and even four times the number of threads in an inch that the woof had. Some of the finest of these mummy cloths appear to be made of yarn of about 100 hanks to the pound, with 140 threads in the inch in the warp, and about 64 in the weft.

If we examine a piece of cloth produced by what is called *plain weaving*, it will be found to consist of two distinct threads or yarns, which traverse the *web*, as the piece of cloth is called, in opposite directions, at right angles to each other. Those threads which form the length of the web, are called the *warp*, and they extend from one end of the piece to the other. The thread or yarn, which runs across the web, is called the weft or woof. This may consist of one thread continued through the whole piece of cloth, passing alternately over and under each yarn of the warp, until it arrives at the outside yarn, when it passes round that yarn, and returns back over and under each yarn as before; but in such a manner that it now goes over those yarns which it previously passed under, and under those yarns which it before passed over, thereby firmly weaving the warp together. Fig. 95 shows the anatomy of a fragment of cloth produced by plain weaving. Variety is produced by causing every third, fourth, fifth, or sixth, &c., threads to cross each other, as in *twilled weaving*, fig. 96, where the same thread of weft remains *flushed*, or disengaged from the warp, while passing *over* three threads, and is held down by passing *under* the fourth thread. Ordinary calico, linen, &c., are produced by plain weaving; while satin, bombazine, kerseymere, &c., are the products of twilled; and to distinguish them from the former, they are called *twills* or *tweels*.

It is usual in modern weaving to arrange the warp horizontally: in the ancient loom, it was suspended vertically, as in fig. 97, with stones suspended at the bottom for keeping the threads stretched. In the modern *Egyptian loom*, fig. 99, the warp is arranged nearly vertically, terminating in a weight for keeping it stretched. Fig. 100 represents an *Oriental winder* preparing the warp threads for the weaver. The Hindoo loom, fig. 98, is also of a very primitive character. It consists of two bamboo rollers, on one of which the warp is wound, and on the other the woven fabric. The threads of the warp are alternately raised by a pair of *healds*, and the weft is inserted by a kind of long netting needle. The Hindoo carries this rude apparatus to a couple of trees, which may afford some shelter, where he digs a hole for a seat, and stretches his warp, by fastening two bamboo rollers at a proper distance from each other, with pins in the turf; the healds he fastens to a branch of the tree or to a bamboo pole stretching from tree to tree, and, with his great toes inserted into two loops which serve for treadles, he thus raises the alternate threads of the warp, inserts the weft, and drives it close up to the web with his long shuttle.

The *common loom*, which has been in use in Europe for ages, is represented in fig. 101. The framework has somewhat the appearance of a four-post bedstead. At one end is the *beam* or *yarn-roll*, A, on which the warp threads are wound; while at the other end is the *cloth-beam*, B, for winding the web. As the web is wound on the cloth-beam, a portion of the warp is wound off the warp-beam, the whole being kept stretched by means of weights, C. The extended threads of the warp are prevented from becoming entangled by means of three flat rods, *r*, *r*, *r*, placed between the alternate threads of the warp. The alternate threads of the warp are raised to admit the shuttle by means of *healds*, *h*, *h'*, consisting of a number of twines looped in the middle, through which the yarns of the warp are drawn. There are two healds, one of which receives every alternate thread of the warp, and the other the intermediate threads. These healds are so united by means of a rope and pulley, D, that the lowering of one causes the other to rise. The warp is also made to pass through the dents or teeth of an instrument called the *reed*, which is set in a movable swing frame, called the *lathe*, *lay*, or *batten*, L (shown separately in fig. 102), since it beats home the weft to the web. At the bottom of this frame is a kind of shelf, called the *shuttle-race*, along which is thrown the *shuttle*, a small boat-shaped piece of wood, containing in a hollow in the middle the bobbin of yarn, the unwinding of which supplies the weft. At the side of the shuttle is a small hole, through which the yarn runs freely as the shuttle moves along. The motion of the shuttle is sometimes assisted by means of rollers, as in fig. 103. The shuttle may be thrown by hand, or the *fly-shuttle* (fig. 104) may be used. In this contrivance the two ends of the shuttle-race are closed up, so as to form short troughs, in which two pieces of wood, called *pickers* or *peckers*, move along wires. To each picker is fastened a string, and the two strings meet loosely in a handle, as shown in fig. 102, which is held in the right hand of the weaver. When the shuttle is in one of the troughs, a smart jerk or pull at the picker projects it along the shuttle-race into the opposite trough, while another jerk in the contrary direction brings it back again.

Supposing the weaver to be in his seat (E, fig. 101), he begins work by pressing upon a treadle, T, by which means one of the healds is lowered, and with it the alternate threads of the warp, which pass through its loops. At the same time, the other heald, with its threads, will be raised, thereby leaving between the two divisions of the warp a space, called the *shed*, fig. 112, for the passage of the shuttle. For every thread of weft thrown across the warp, the weaver has three things to do: *first*, to press down one of the treadles so as to form the shed; *secondly*, to throw the shuttle across the warp; *thirdly*, to drive the thread of weft close up to the web, by means of the batten, fig. 102, which he guides with the left hand. A thread of weft being thus formed, a second thread is next thrown in the opposite direction, for which purpose the other treadle must be depressed so that the warp threads, which were before elevated, are now lowered. As the weaving proceeds, the finished cloth is wound upon the cloth-beam, by turning a handle at the side; the beam being prevented from slipping by means of a rachet wheel. The cloth is kept extended in breadth by two pieces of wood called *temples*, fig. 105: these are furnished with points at the ends, which are inserted into the edge or selvage of the cloth at either side.

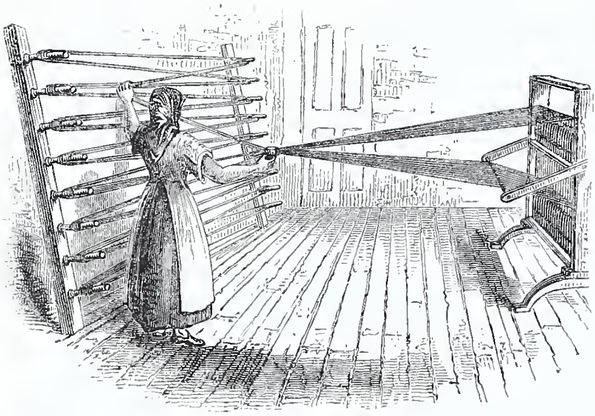
Weaving is a very easy operation: a little care is required not to depress the treadles too far or too suddenly, or some of the warp threads may be broken, and much time be lost in repairing them. The friction of the dents of the reed renders the threads liable to break. Care is also required in throwing the shuttle. If thrown too violently, it may recoil, and, by slackening the thread of the weft, injure the appearance of the fabric; and if not thrown far enough, it may injure the warp threads. The

batten must also be brought up against the shoot with an equal degree of force at every stroke ; otherwise the cloth will not be of uniform thickness, and the degree of force with which the batten is brought home must vary considerably, according as the goods are coarse and thick, or fine and light.

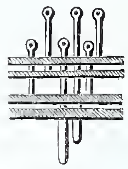
The labours of the hand-loom weaver long since proved as inadequate to satisfy the demand for woven goods, as the old spinning-wheel did for the supply of yarn. It had long been a mechanical problem to weave by machinery, and many attempts were made to solve it, among which must be noticed the invention of Dr. Cartwright. This gentleman had a natural genius for mechanical construction ; and although not educated as a mechanician, he could not resist his natural impulse to invent. His attention was excited by the success of Arkwright's spinning machinery ; and happening, in the summer of 1784, to hear a Manchester man remark, that on the expiration of Arkwright's patents, so much cotton would be spun that hands would not be found to weave it, Cartwright remarked that Arkwright must set his wits to work and contrive a weaving mill. The possibility of weaving by machinery was denied ; but the good doctor was so impressed with the idea, that he set to work, and, with the assistance of a carpenter and a smith, produced his loom. He then got a weaver to put in the warp, and succeeded in weaving by its means a piece of sail-cloth. In this first attempt too much power was used. "The warp," says the doctor, "was placed perpendicularly ; the reed fell with a force of at least half a hundredweight ; and the springs which threw the shuttle were strong enough to have thrown a congreve-rocket: in short, it required the strength of two powerful men to work the machine at a slow rate and only for a short time." This rude beginning was patented in 1787 : it entailed upon the inventor loss of property, and vexation of mind, consequent on the determined opposition of the operative weavers ; until at length it was generally adopted as being as necessary in its way to the prosperity of the country as Arkwright's machinery itself. We now see it at work thousands in number under a single roof, as in Ackroyd's loom-shed, fig. 114, where the restless activity of the shuttles, and the other moving parts, so completely occupy the air with their vibrations, as to render speech and hearing useless. Here we see beautiful fabrics, as it were, producing themselves ; the presiding mind which directs the whole not being apparent to the casual visitor ; while the unskilled attendant takes the charge of two or three of these looms, and should any one of them go wrong, or should the shuttle require a new cop, stops that particular loom for an instant, supplies the defect, and sets it rattling on again. In some cases the services of the attendant are not even required ; for the loom itself, should a thread break, or the shuttle be run out, will stop itself, and ring a bell to give notice that it has left off work. Nor is it upon plain weaving alone that these wonderful automatons are so active. In this same Ackroyd's loom-shed we see beautiful and complicated patterns growing before our eyes, and are half disposed to attribute to the machine itself a portion of that intelligence which produced it and set it going.

The essential parts of a power-loom, detached from their framing, are shown in fig. 106. The warp is wound round the beam A, and passing up over a roller, B, is carried through a couple of healds, D E, which form the shed for the passage of the shuttle, F, which is driven along the shuttle-race by a kind of hammer, worked by a lever, moving through a small arc of a circle. The finished cloth, G, kept stretched by the temples, H, is wound upon the cloth-beam, I. In such an arrangement, five distinct actions are performed by steam-power ; each loom being connected by an endless band with the shafting overhead (see fig. 114), which is driven round by the steam-engine of the establishment. Of the five actions referred to, the *first* is to raise and depress the alternate threads of the warp so as to form the shed, fig. 112. *Secondly*, to throw the shuttle. *Thirdly*, to drive up each thread of weft with the batten. *Fourthly*, to unwind the warp from the warp beam. *Fifthly*, to wind the woven material on the cloth roller. To these may be added a *sixth ;* the stopping the loom on the breaking of a thread, or when the shuttle traps, that is, sticks in its course through the thread, or when the shuttle becomes empty. In any one of these emergencies, a lever is set in motion, which thrusts aside the strap or endless band from off the pulley which turns the loom, to a loose pulley at the side, where it continues to revolve without acting on the loom.

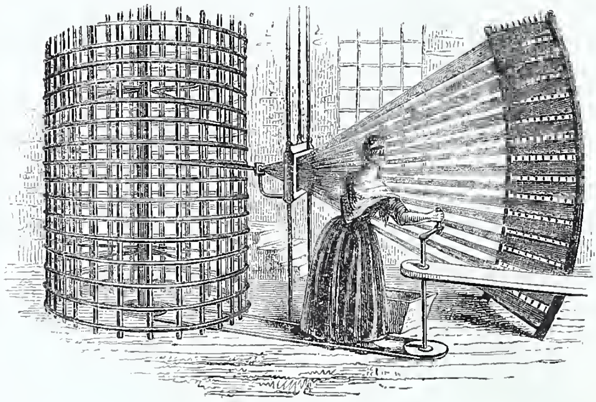
The weaving of patterns by machinery brings us to speak of the beautiful *Jacquard apparatus*, which is an addition to the loom, for raising certain threads of the warp in a certain predetermined order ; so that on throwing the weft of one colour, or shuttles each containing a different colour in a certain prescribed order, a pattern shall be produced. We hope to make this more intelligible as we proceed. Before Jacquard's invention, a clumsy apparatus, called the *Draw-boy*, was in use in pattern-weaving. Jacquard was originally a straw-hat manufacturer of Lyons, in France. His dormant mechanical genius was excited by an advertisement offering a reward to any one who could produce a net by machinery. He produced such a machine, and, with the modesty or indifference of an original mind, threw his invention aside as soon as he had perfected it. By some accident a net woven by this machine was shown to some persons in authority : the Prefect of Lyons sent for the inventor, and a new machine was ordered to be constructed. In the course of three weeks this was completed and was laid before the Prefect, who, on striking a given part of the machine with his foot, saw to his surprise a new mesh added to the net. Napoleon I., who, about this time, was the liberal patron of any invention which was likely to injure the commerce of his unconquered and unconquerable rival, Great Britain, sent for Jacquard to Paris. On his arrival there, he was requested to deposit his machine at the *Conservatoire des Arts et Métiers*. This was accordingly done, and the machine was favourably reported on, whereupon the Emperor sent for the inventor, and at first sight of him called out : "Are you the man who can perform the impossibility of tying a knot in a stretched string ? " In answer to this strange question, the inventor produced his machine, and formed the meshes by tying the strings, where they crossed, into hard knots, after the common manner of net-making. Napoleon, as usual, catching at a glance the talent of the man, and seeing what he was fit for, sent him to examine a loom employed in the production of articles for the use of the court, on which from 20,000 to 30,000 francs had been already expended. This loom, based on an idea of the celebrated mechanician, Vaucanson, was for the production of patterns by machinery. Jacquard undertook to produce the desired result by simpler means, and accordingly he invented the celebrated apparatus which bears his name. He was rewarded by the Government with a pension, and was permitted to return to Lyons. No sooner, however, did he make his apparatus known, than the usual fate of inventors awaited him. He experienced the most violent opposition from those whom his invention was best calculated to serve : on three occasions he narrowly escaped with his life, and during the political troubles of France his machine was condemned by the town-council of Lyons : it was brought out into the market-place, broken to pieces, and its inventor covered with ignominy. In the course of a few years, however, when other countries had appropriated this beautiful invention, and by its means were rivalling the choicest productions of Lyons, the Lyonnese saw their error, and the much-despised apparatus was soon in active operation in all the silk, worsted, and muslin manufactories of the country. The Lyonnese sought to atone for their ingratitude by means of a memorial to their persecuted townsman : this was a woven portrait of Jacquard, representing him in his workshop, surrounded by his implements, "planning the construction of that beautiful machinery which, now in increased perfection, returns this testimony to the genius of its inventor." This piece of Jacquard weaving is spoken of as a very wonderful performance, on account of the fineness of the work (there being 1,000 threads in each square inch both of the



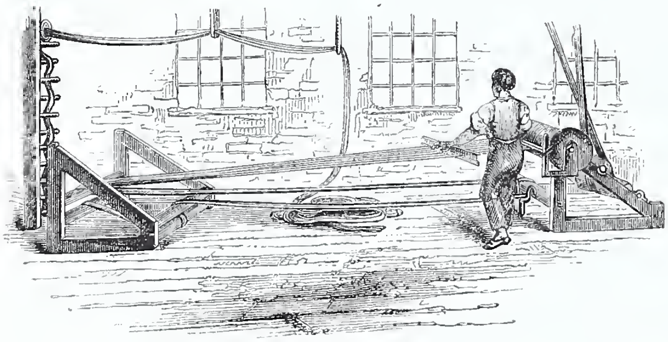
115. WARPING FRAME.—(*Woollen Yarn.*)



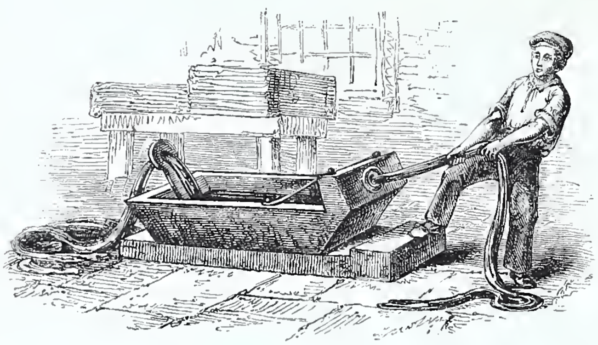
117. HECK.



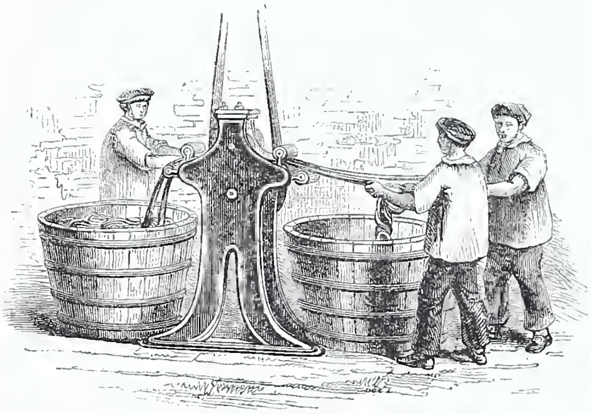
116. WARPING MILL.



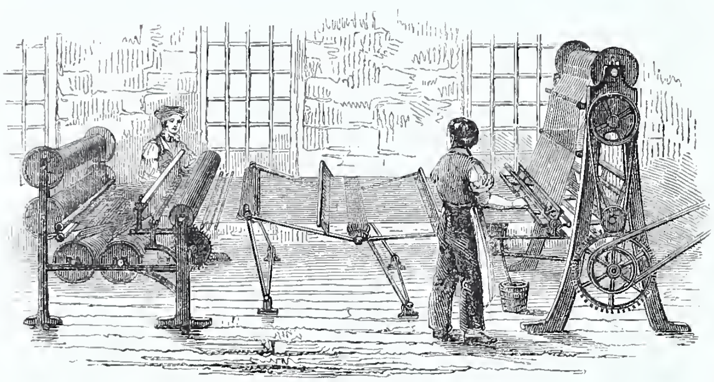
118. BEAMING.—(*Cotton Yarn.*)



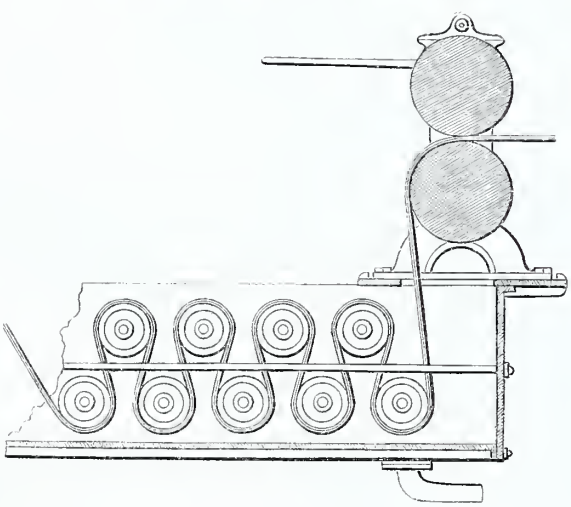
119. SIZING.—(*Woollen Yarn.*)



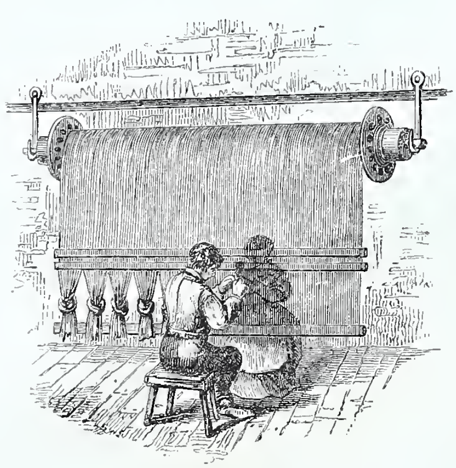
120. SCOURING WORSTED YARNS.



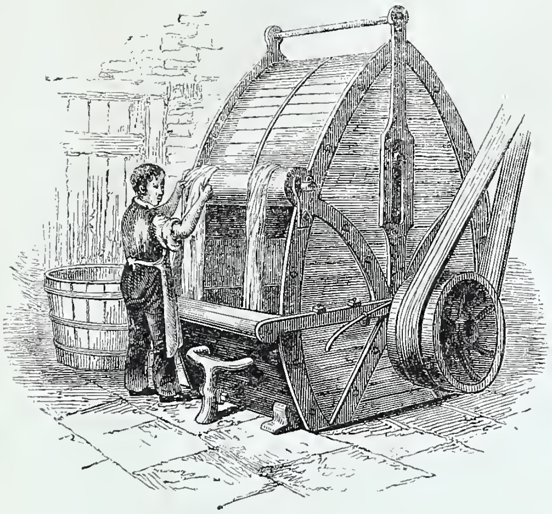
121. DRESSING AND SIZING.—(*Cotton Yarn.*)



122. SIZING MACHINE.

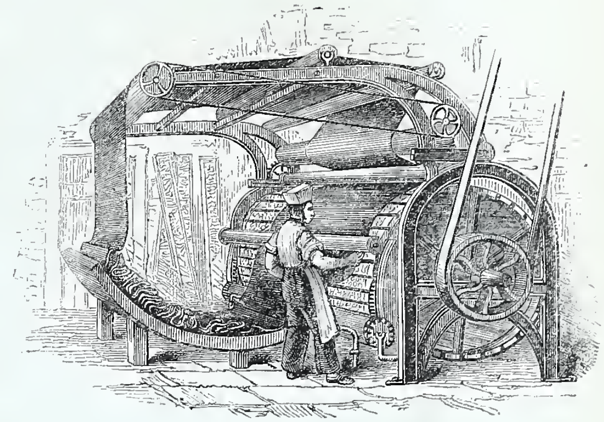


123. DRAWING IN.—(*Woollen Yarn.*)

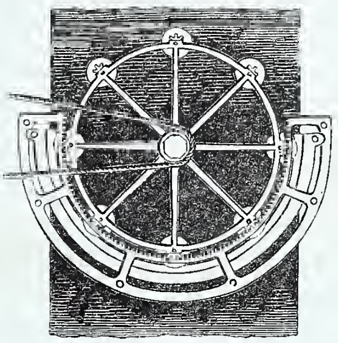


124. SCOURING MACHINE.

125. THE TEAZLE (*Dipsacus fullonum*).

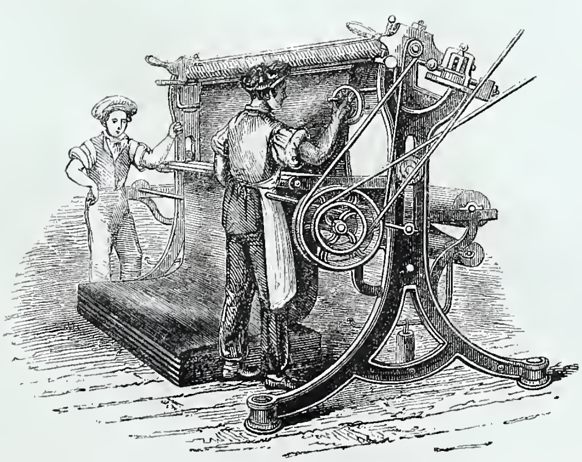


126. GIG-MILL FOR TEAZLING CLOTH.

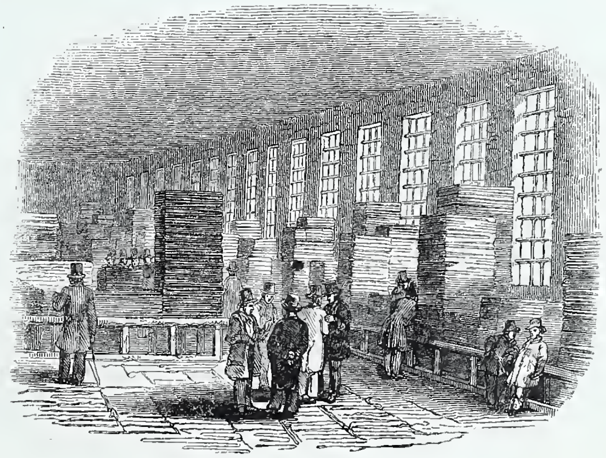


127. SHEARING MACHINE.

128. FULLING STOCKS.



129. BROAD-PERPETUAL, FOR SHEARING CLOTH.



130. INTERIOR OF CLOTH HALL, LEEDS.

warp and of the weft) and the mechanical difficulties of the undertaking: we should be better pleased if such performances as these were impossible. It is no merit to accomplish with difficulty in the wrong material that which can be effected with ease in the right. A portrait of Jacquard in oil, or a statue in stone or marble, is a legitimate performance; but a portrait woven in a silk handkerchief, whether easy or difficult of performance, is in false taste. A portrait is not meant to be folded up or crumpled in the hand, but to be exposed constantly to view on a rigid surface and in a vertical position. To this end, freedom of expression, bold handling, and judicious laying on of colour, are requisite; effects which cannot be produced by mechanical means, least of all by the loom; they cannot by produced by the needle, and hence we object to the representation of the human form, or of animals, or landscapes in needlework, in worsted work, or any material not recognised by the true artist.

The Jacquard apparatus is attached to the top of the loom in a line with the healds, so as to act upon the warp threads. It must be understood that in figure-weaving, in addition to the ordinary play of the warp, for the formation of the ground of the web, all those threads which must rise at the same moment in order to produce the pattern, have their proper healds. In the draw-loom these were raised by means of cords, which grouped them together in a system, so as to be raised in the order and at the time required by the pattern. In the Jacquard apparatus, the warp threads are raised by a number of wires, arranged in rows, each wire bent at top into a hook, and these hooks are supported by bars, the ends of which are seen in fig. 107. The bars are supported by a frame, which is alternately raised or lowered by a lever attached to and acting with the treadle. If all these bars were raised at once, all the warp threads would be elevated; but if by any means some of the hooks were pushed off the bars, while the others were allowed to remain on, the warp threads in connexion with the latter would only be raised. Now the hooks are disengaged from the bars by means of horizontal wires or needles, one of which is shown separately in fig. 110: each wire has a loop or eye in the centre, through which the vertical lifting wires, fig. 107, pass. The horizontal needles are kept in place by means of spiral springs contained in a frame, fig. 107, and the points of the needles project on the opposite side of this frame. Now it is evident that if a slight pressure were applied to any of the points, the needles would be driven into the frame. The vertical wires would be disengaged from the bars, and the warp threads in connexion with them would not be raised. On the removal of this pressure, the elasticity of the springs would drive the needles forward and restore the hooks to the bars.

The method of driving the needles back at the proper time so as to raise the different portions of the warp required to form the pattern, is by means of a revolving bar of wood (fig. 108), the sides of which are pierced with holes corresponding in numbers and position with the points of the needles. One of the sides of this bar is brought up against the points of the needles every time the treadle is depressed. If, however, this alone were done, the points would enter the holes, and no effect would be produced. But if some of the holes were stopped while others remained open, some of the needles would be driven back and others would remain undisturbed, and the warp threads in connexion with these latter would alone be raised. This is what is done in practice: each face of the revolving bar is covered with a card containing a smaller number of holes than those of the bar; so that when the points of the needles press against an unperforated part of the card, they are driven back, but when the points enter the holes of the card, they enter also the holes of the drum, and the needles corresponding thereto remain unmoved. In this way the pattern is made out; the revolving bar presents a new card to the points of the needles at every quarter turn, supposing the bar to be four-sided. As the holes in the cards are arranged so as to raise in succession those healds which will make out the intended pattern, it is evidently necessary to have as many cards as there are threads of weft in the pattern. All the cards are tied together by the edges, so as to form a kind of endless chain, one complete revolution of which makes out the pattern; and by repeating it, the pattern may be repeated on the warp.

The preparation of these cards requires care. The pattern is drawn upon squared paper: that is, the order in which the threads are grouped is marked upon a *pattern paper* or *design*, as it is called, so divided by lines into squares as to represent a woven fabric on a large scale, the threads which make out the pattern being put in in appropriate colours. The pattern is next repeated in a frame containing a number of vertical threads, corresponding with the warp, when the workman with a long needle takes up such threads as are intersected by the pattern, inserts a cross-thread under them, and carries it over all the remaining threads in the same line, and he repeats this process until he has inserted a sufficient number of weft-threads to make out the pattern. The threads thus interlaced are attached to a card-punching machine. This acts on a principle identical with that of the Jacquard apparatus itself. It is furnished with lifting cords, wires, and needles, connected in the manner explained for fig. 107, so that on pulling the lifting cords the needles are protruded. In front of these needles, and answering to the revolving-bar, fig. 108, is a thick perforated iron or steel plate, each of the perforations of which contains a movable steel punch or cutter; so that on causing any of the needles to protrude they will drive before them their corresponding punches, and deposit them in a second iron plate, similarly perforated, placed against the face of the former one. Now, the method of protruding the steel punches required for each card is as follows:—One end of each warp thread in the pattern frame is connected in succession with the individual lifting cords of the machine: each thread of the weft is then taken by the two ends and drawn upwards, by which means all the warp threads passed under by this weft thread will be raised, and can be collected together in the hand: on pulling them, the particular lifting cords to which they are attached will cause the needles to protrude; these will drive out the cylindrical cutters which occupy the perforations of the fixed plate into the corresponding cavities of the movable plate. A blank card-slip is placed against the latter, which is taken to a press, where the punches are driven through the slip (fig. 109). The process being repeated for the other cards required to make up the pattern, the various cards are numbered and attached together in their proper order. The number of cards may vary from a few hundred to many thousand. The cards are arranged in folds, and partly supported upon a curved board over the loom, as shown in fig. 114.

Before the loom can be set to work, a number of preparatory steps have to be taken, which could not well be explained until the nature of weaving and the structure of the loom were understood. The preparation of the warp involves many details which may be included under the general term of *warping*, whereby all the warp threads are arranged alongside of each other in one parallel plane. That this is an operation requiring much care will be evident from the fact that in a width of twenty inches, as in silk goods, there may be eight or ten thousand threads, every one of which must occupy its proper place without entanglement or confusion. One of the oldest methods of warping was to draw out the threads in an open field, as is still done in India and China. Our uncertain climate and superior mechanical skill do not countenance so primitive a proceeding. An old arrangement, which we have copied from the woollen manufacture, is represented in fig. 115. This *warping frame* consists of two uprights, with a number of projecting pins for receiving the yarns, while the bobbins containing them are mounted in a frame. The warper ties all the ends of the threads together, attaches them to one of the pins, and, collecting them in one hand, walks to the other end of the frame, passes them over a pin, and so on backwards and forwards until the desired length has been collected. Another method, represented in fig. 116, is

the *warping mill*, consisting of a large reel, mounted on a vertical axis, to which motion is given by means of an endless band, which connects the bottom of the axis with a wheel turned by the warper. The bobbins of the yarn are mounted on skewers in a frame on the right, called a *travers.* The yarns from the bobbins are made to pass through a *heck*, fig. 117, also called a *jack* or *heck-box*. As the reel, fig. 116, revolves, the heck slides up and down between a couple of posts, whereby the warp yarns are wound spirally and smoothly over the sides of the reel. The use of the heck is to form the *lease*, that is, to divide the warp into two alternate sets, one for each heald, for which purpose the heck-block contains a number of steel pins, with a round hole or eye in the upper part of each, through each of which a yarn is passed. The pins are placed in alternate order in two frames, either of which may be raised at pleasure. The warper preserves the lease or crossing of the threads by tying through them at the top, just below the knot which fastens the ends of the yarn together, and before the warp is removed from the mill the yarns are tied together at the ends. The warp is made up into a bundle for the next operation, which may vary according to circumstances. Supposing it does not require to be strengthened by the application of size, it may be wound upon the yarn beam of the loom. The operation is called *beaming*, and is represented in fig. 118. The beam turns upon iron pivots, and is set in motion by being put into gear with a revolving shaft overhead; and the workman, holding in his hand a sort of comb, called a *separator*, or *rabble*, through the cane teeth of which the warp threads are passed, thus spreads the warp smoothly and evenly upon the beam.

As the warp is subject to considerable tension and friction during the process of weaving, it is usual to give it a dressing of glue, size, or paste, in order to strengthen it. This may be done, as in fig. 119, by passing portions of the warp through a hole in a trough, under a couple of rollers in the bottom of the trough, and then out at another hole in the side, which squeezes out the superfluous fluid, and so backwards and forwards several times. In the worsted manufacture, the yarns require to be *scoured*, to get rid of the oil used in the combing. They are immersed in a tub of soap-suds, as in fig. 120, passed between pressing rollers, and then *linked* or plaited, to prevent the warp threads from becoming entangled. Dressing and sizing are sometimes performed after the beaming, for which purpose the beams are mounted in frames, as in fig. 121; and the threads, being passed through reeds to keep them distinct, pass between a couple of rollers covered with felt, one of which dips into a trough of paste. Cylindrical brushes rub the size into the fibres, and distribute it over their surface. The yarn is then dried by being passed over a chest filled with steam, and is finally wound upon the main yarn-beam. The yarns are also sized by means of the *sizing machine*, fig. 122, which consists of an iron trough surrounded by a case filled with steam, and called a *steam-jacket*. The trough also contains a number of rollers, over which the warp travels up and down, so as to keep the yarns longer in the warm fluid size, and, having passed out of the trough, the superfluous moisture is squeezed out by means of two large wooden rollers, after which the warp is dried by being passed over the cylinders of a *drying machine.*

The warp having been wound on the warp-beam, the next process is *drawing-in*, or passing every yarn through its proper eye or loop in the healds. For this purpose the yarn-beam is suspended by its ends, as shown in fig. 123, and the healds are also hung up near the free hanging ends of the warp yarns. The weaver and his assistant are seated one on one side and the other on the other side of the healds, and the assistant picks up each thread in its order, as determined by the lease rods, to be drawn through the open eyes of the healds. The warp is then passed through the splits of the reed, portions of the warp being tied into knots as the drawing-in is completed, and these knots are connected with a shaft which is attached to the cloth-beam of the loom. The fineness of the cloth, or the *number* or *set of the reed*, depends on the number of dents of the reed in a given length, two threads passing through each dent. Thus a 60 *reed cloth* contains sixty warp threads in an inch. This simple method, however, is not followed at all places.

VI.—FINISHING PROCESSES.

WOOLLEN CLOTH.

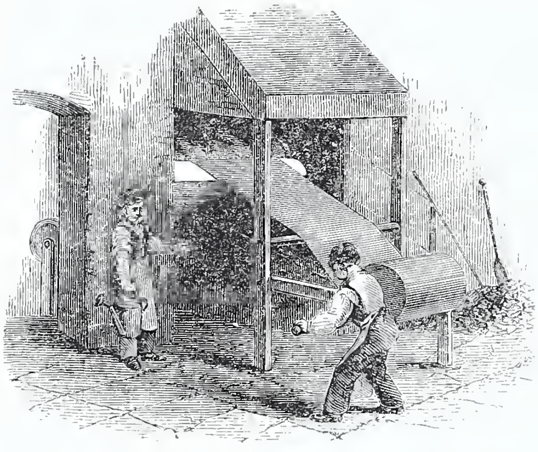
When the weaver has done his part, and the fabric is removed from the loom, it is seldom fit for use (except in the case of silk goods), but has to undergo a number of finishing processes, such as *fulling*, *teazling*, *shearing*, *singeing*, *bleaching*, *dyeing*, *printing*, *calendering*, *starching*, *making up*, &c. We shall have to notice all these processes; but we will first describe those which are peculiar to woollen cloth.

Broad cloth is woven in looms of large size, the width of the cloth being upwards of twelve quarters, in order to allow for the shrinking which takes place in the finishing processes. The edges of the cloth are finished with a narrow border of list, made of goat's-hair, or of coarse yarn, for the purpose of receiving the tentering-hooks, when stretched out to dry.

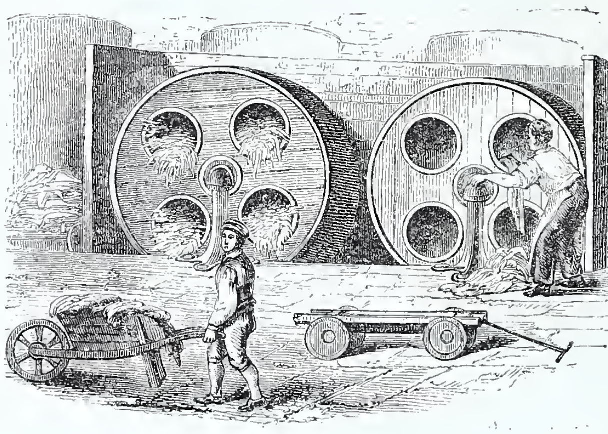
The first finishing process for woollen cloth is *scouring*, in order to get rid of the oil used in spinning, and the size in dressing, the warp. Scouring consists in constantly agitating the cloth in water containing some detergent substance, such as *Fuller's earth*, the alumina of which forms a soap with the grease, and is thus rendered soluble, and capable of being removed by washing. The *fuller's stocks*, next to be described, are also used with a quantity of soap and warm water, after which the cloth is passed through a *scouring machine*, fig. 124, and washed in hot water with the assistance of squeezing rollers.

The *fulling mill*, fig. 128, consists of ponderous oaken mallets working in a *stock* or frame. The mallets are worked by *tapit wheels*, or wheels with projecting cogs, which bear on the shanks of the mallets, raise them to a certain height, and, suddenly releasing them, allow the heavy heads to fall by their own weight into an inclined trough, the end of which is curved. The cloth, being put into this trough, is exposed to the blows of the mallets, and by the form of the trough is turned round and round, so that every part may be acted on. At first the cloth is impregnated with soap, as already noticed. When this has been removed by washing, the cloth is returned to the fulling-mill, with fresh quantities of soap; where it is exposed for many hours to the action of the mallets, the object being now not to clean or scour, but to *felt*; that is, to produce such a motion among the fibres of the wool that their minutely jagged surfaces may lock into each other, so that the individual threads are lost under the thick fulled surface which is raised upon them. The fulling stocks differ from the scouring stocks in the form of the trough, the end of which is square instead of inclined; so that the cloth receives the direct blows of the mallets, instead of being turned round and round. Indeed, it seems wonderful that the cloth is not pounded to a soapy pulp under the continuous blows of the ponderous mallets. An ordinary broad-cloth requires from sixty to sixty-five hours to full, and about eleven pounds of soap; it shrinks during the process from twelve quarters wide to seven, and from fifty-four yards in length to forty yards. Of late years the fulling-stocks have been superseded in great measure by the *fulling-machine*, where rollers do the work of the mallets, in a shorter time and with a less expenditure of soap.

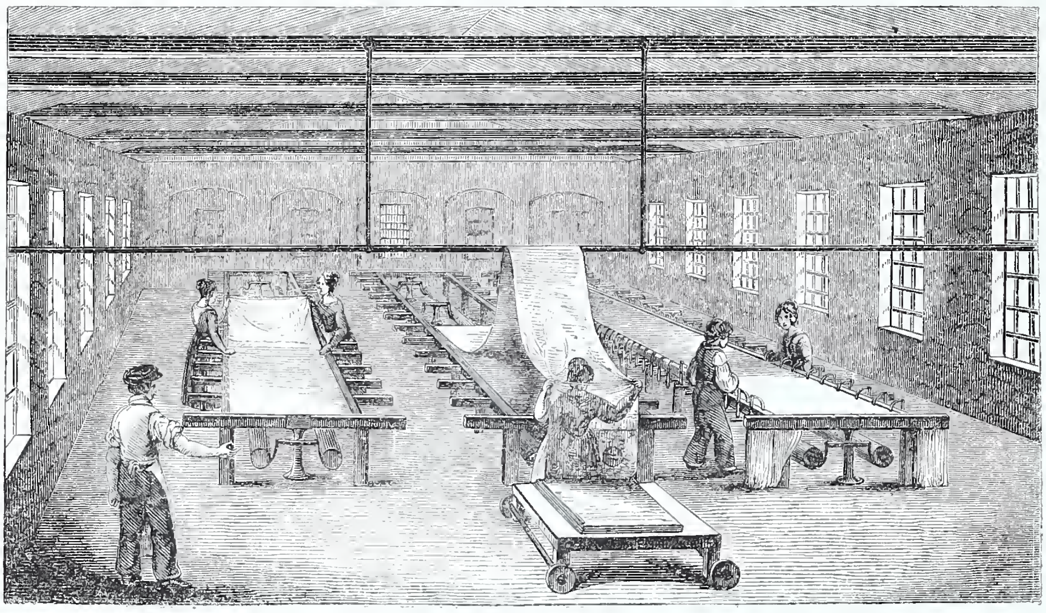
After having been dried, the cloth is dressed at the *gig-mill*, fig. 126. It is first *roughed* or *rowed* for about twenty hours with teazles, the object being to raise the wool on the surface.



131. SINGEING CALICO.

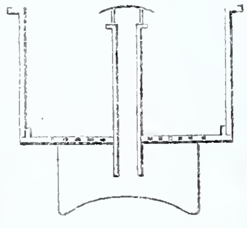


132. DASH-WHEELS.

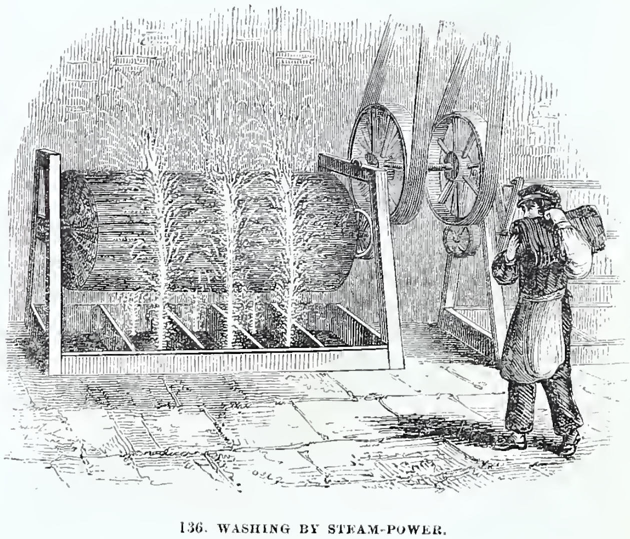


133. DRYING ROOM. (*Muslins.*)

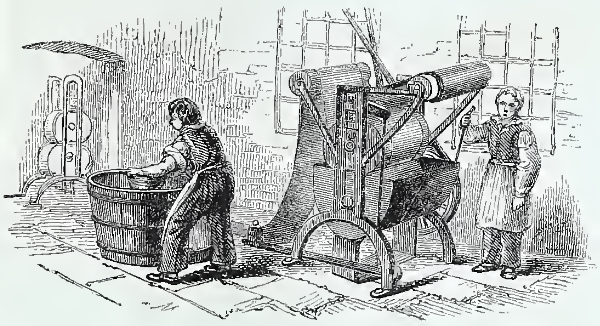
134. BOWKING KEIRS.



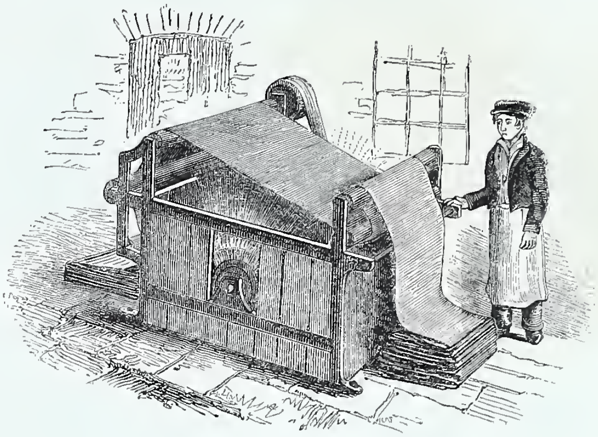
135. SECTION OF KEIR.



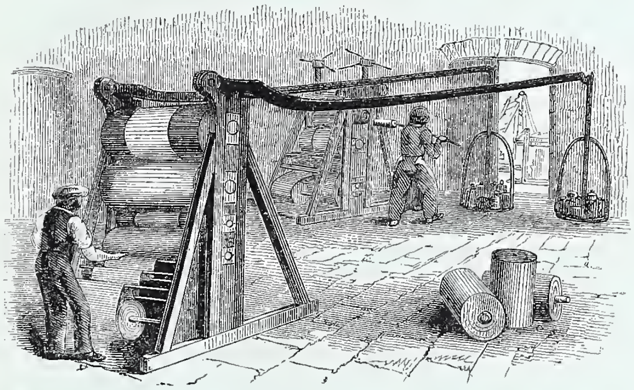
136. WASHING BY STEAM-POWER.



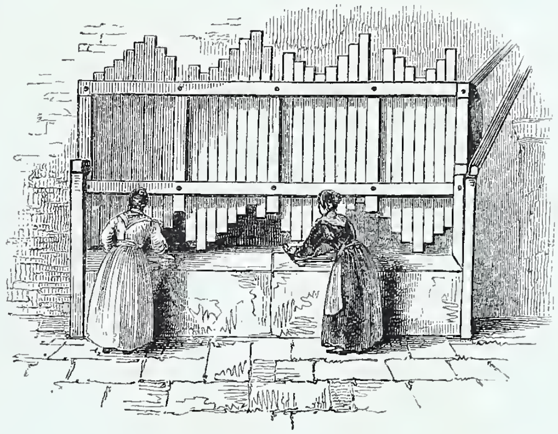
137. STARCHING MACHINE.



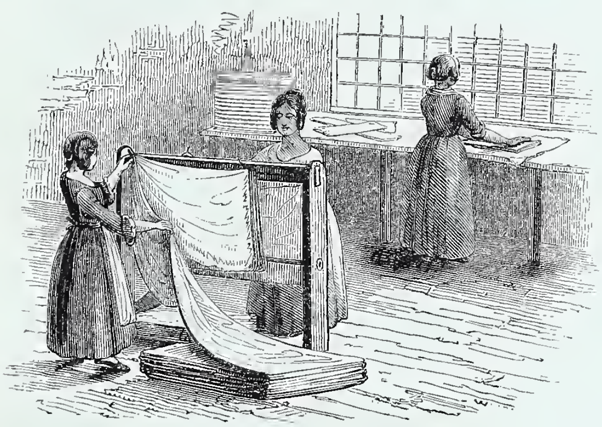
138. DAMPING MACHINE.



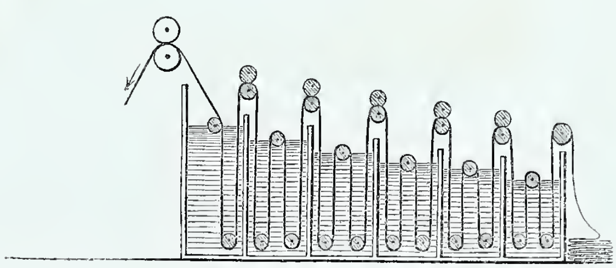
139. CALENDERING MACHINE.



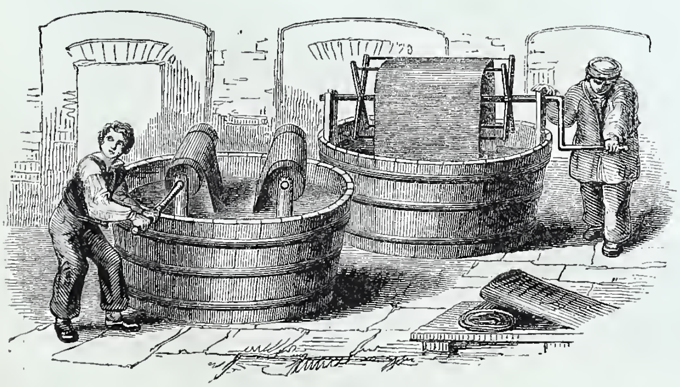
140. FLAT BEETLE.



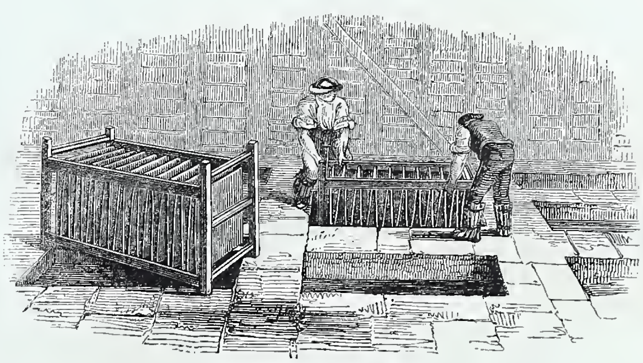
141. HOOKING FRAME.



142. RINSING MACHINE (*Vertical Section*).



143. DYE-BECKS.



144. DYEING IN INDIGO BLUE.

The teazle is the prickly flower-head of a species of thistle (*Dipsacus fullonum*), fig. 125, which is cultivated for the purpose. As many as from 2,000 to 3,000 teazles are required for a piece of cloth forty yards long. Each head consists of a number of flowers, separated from each other by scales; and at the end of each scale is a fine hook, which is the efficient part in teazling cloth. When a number of these heads are mounted in a frame, and brushed against the cloth so as to comb up or raise up a nap on its surface, any kind of entanglement between these natural hooks and the cloth does not produce a rent or tear in the fabric, but the natural hook gives way. This effect is not easy to imitate artificially, however desirable it is to do so, since teazles form an uncertain crop and are costly. In the gig-mill the teazles are arranged in long frames attached to a hollow drum, and the cloth, guided by rollers, is moved in a direction contrary to that of the drum.

The fibres of the wool brought to the surface by teazling, being of unequal length, are next shorn, in order to make them level. For this purpose the arrangement shown in fig. 127 may be used, where there is a fixed semicircular rack, within which is a cutting edge or *ledger-blade*, and a large revolving wheel containing eight small cutting disks, which in contact with the ledger-blade form a number of cutting shears, each disk having a toothed pinion working into the semicircular rack; so that as the large wheel revolves, the cutting disks have an independent rotatory motion in addition to their revolution with the large wheel. In the figure the cloth is represented by the dark shaded portion. It is more usual, however, to employ the machine represented in fig. 129, which is called a *broad perpetual*, or in another form the *cutting machine*, which consists of an iron cylinder with cutting blades passing spirally round it, while in contact with them and parallel to the cylinder is a straight steel blade, so that anything placed between this blade and the cutter blade will, when the cylinder turns round, be cut as with a pair of scissors. The cloth to be sheared is passed over another steel blade directly below the cutter; and the raised fibres, being exposed to the action of the latter, are sheared off. For fine cloth the teazling and shearing are repeated.

The cloth is next arranged in regular folds with polished pressing boards between them, and subjected to the action of a hydrostatic press. Hot iron plates are sometimes used for the purpose, in order to give a satiny lustre and smoothness to the face; but as this is apt to become spotted by rain, it is exposed to hot water or to steam, which prevents the spotting by rain. The cloth is also several times passed through a brushing machine, and is carefully examined, for the purpose of closing by hand any minute hole or break in the fabric, and also for touching with dye stuff any spot which may not be of the proper colour.

Halls for the sale of cloth are established in the Yorkshire districts. Fig. 130 represents the interior of the Coloured Cloth Hall at Leeds.

VII.—FINISHING PROCESSES.

BLEACHING, CALENDERING, DYEING, &c.

CALICO, muslin, and other descriptions of cotton goods intended for sale in a white state, require to be bleached. The old method of doing this was to send the goods (chiefly brown linens) to the bleaching grounds of Holland, where, after some preparatory processes, they were spread out on the grass and sprinkled with pure water several times a day. In the course of several months' exposure to air, light, and moisture, they became bleached; and on being returned to this country, were distinguished by the name of *Holland*.

Many attempts were made to abridge this tedious process of bleaching; but none were very successful until about the year 1785, when it was discovered that one of the constituents of common table salt possessed the property of destroying vegetable colours. Common salt is a compound of chlorine and the metal sodium; and is called in chemical language *chloride of sodium*. When the chlorine is separated from the sodium, it assumes the gaseous form, and is of a yellowish-green colour, whence its name, from the Greek word for *green*. The most convenient method of applying the chlorine for the purposes of bleaching is in combination with lime, forming the well-known bleaching powder, chloride of lime. A solution of this can be made with water, by which means the noxious qualities of the chlorine are avoided; this gas being, even when largely diluted with air, exceedingly irritating to the lungs, and producing suffocation in its more concentrated form.

There are several circumstances which interfere with the whiteness of cotton goods. The fibres of cotton are covered with a resinous substance, which prevents them from readily absorbing moisture; and also with a yellow colouring matter, which seems to be confined to the surface. This colouring matter is sometimes so small as to render bleaching unnecessary, were it not that during the spinning and the weaving the goods acquire certain impurities. The weavers' dressing has to be removed, together with quantities of rancid tallow or butter, used to soften the dressing when it has become rigid. There are also soapy and earthy matters, and the dirt of the hands, to be removed. When the goods are received at the bleach works, they are marked with the owner's name, with a needle and thread, or stamped with a wooden stamp, dipped in coal tar. Then comes the curious process of *singeing*, the object of which is similar to that already noticed for cotton yarn or thread, fig. 34; namely, to remove the fibrous down or nap from the surface of the goods, which would otherwise injure their appearance, and, in the case of coloured goods, prevent them from receiving the dye stuff properly. The singeing is a simple operation: a number of pieces of cloth are fastened together at the ends and wound upon a cylinder, the axis of which has a winch handle. The cloth is then drawn over a red-hot copper flue, as shown in fig. 131, which singes off the nap; after which it is conducted over a metal roller, which plays in a trough of water. The cotton is usually passed three times over the hot flue; twice on the *face*, or the side intended to be printed on, and once on the back. It is wound from one roller over the heated bar to another roller on the other side of the furnace; and there is a swing frame for lifting the cloth off the hot metal when required.

Each piece of cloth is next made up into an irregular bundle, and steeped in water for twelve or fourteen hours. It is then washed in a *dash wheel*, fig. 132, which consists of a cylindrical box revolving on an axis, containing four divisions with an opening in each, into which the pieces are put. A large quantity of water is admitted from behind, and the wheel is set in rapid motion; which gives to the pieces the amount of friction required for their washing. This removes much of the dirt and weaver's dressing, but not the grease. To get rid of this, it must be combined with an alkali, such as caustic soda; but lime, being cheap, is largely used for the purpose with boiling water, in a *bucking* or *bowking-keir*, fig. 134. It is also called a *puffer*. Its arrangement will be understood from the vertical section, fig. 135. It consists of two parts; an iron pan set in brickwork, with a fire underneath, and a cast-iron vat, for containing the goods, separated from the pan by a grating. In the centre is an iron pipe with a curved cover. The liquor in the pan, from the pressure of the cloth above it, cannot escape into the vat, except by passing up the central pipe; and as the steam accumulates, it forces up a quantity of hot alkaline liquor, which being reflected back by the curved cap, pours down upon the cloths, and drenches them, filters through them into the boiler, to be again raised and poured down as before. The boiling is continued for seven or eight hours.

The pieces are now clean ; but the action of the lime has been to make them darker in colour than they were before. The lime is washed out at the dash wheel, or in a wheel shown in fig. 136, when they are fit for *chemicking*, as the treatment with the bleaching powder is called. The bleaching is conducted in stone vats, over each of which is a perforated trough ; so that the liquor can be pumped up and rained down upon the goods. Care must be taken that the bleaching solution be not too strong, or it will make the goods run into holes. After about six hours, the cloth is of a light grey colour.

The next process is *souring*. The goods are steeped in a weak solution of sulphuric acid for four hours ; the action of which is to decompose the chloride of lime, and by setting free the chlorine within the fibres of the cloth, to remove the colour. The acid also removes minute portions of oxide of iron ; and the goods, when removed from the solution, are much improved in colour, though not sufficiently bleached. They are therefore boiled in a potash or soda *ley*, then washed at the dash wheels, again immersed in the bleaching solution, and after a thorough washing, become quite white.

This description applies to the bleaching of cotton shirting and the better descriptions of cotton fabrics which are to be printed on. The bleaching processes vary somewhat for different descriptions of cotton and linen goods. Wool is bleached by exposing it to the fumes of burning sulphur, or by steeping the goods in a solution of sulphurous acid.

After the cotton or linen goods leave the bleacher, they are passed to the calenderer ; whose business it is to make the surfaces compact, level, and uniform, and otherwise improve their appearance. Each piece of cloth is drawn out to its full extent by being dragged through a cistern of water, on its way to a pair of rollers, and the edges are beaten out by knocking them against a smooth beating-stock. The pieces are then stitched end to end, and passed through a mangle, consisting of a number of rollers, and is next wound upon a roller to be starched. The starch is blued by the addition of a little indigo, and is often thickened with an equal bulk of porcelain clay, or equal parts clay and calcined plaster of Paris ; the effect of which is to produce an apparently strong and thick cloth, an artifice which cannot be referred to without a word of censure. The *starching-machine*, fig. 137, consists of a trough for holding the starch, and a couple of rollers pressed together by levers; between which the cloth passes after dipping into the trough, and the superfluous starch is thus pressed out. After this the goods are dried upon cylinders made hot by being filled with steam ; or the more delicate fabrics, such as muslins, are stretched between long frames, as in fig. 133, and dried in a room heated to about 100° by steam pipes. To prevent the muslin from becoming rigid during the drying, the two long sides of each frame are made to work backwards and forwards through a small space in opposite directions, lengthwise.

Many kinds of cotton goods require *glazing* or *calendering*, properly so called. The goods are damped by being passed over a revolving brush which raises the water in a fine spray, fig. 138, and are then passed between rollers, which are pressed together by means of long levers, weighted at the further end, fig. 139. When the rollers are smooth, the threads of the fabric are flattened, and a soft silky lustre is given to the surface. When two surfaces are passed between the rolls at the same time, the threads make an impression upon each other and a kind of wiry appearance is given to the surface. The rollers are of various materials, such as iron, wood, paper, and calico, and require very nice workmanship in their preparation. Some of the rollers are of copper, engraved with a variety of figures and patterns, by which figured velvets are produced. The *water-surface* is produced by variously engraved or indented rollers. Variety is also obtained by heating one of the rollers by means of a red hot iron placed in it. The surface of some goods, such as jacconets, Irish linens, &c. is modified by means of wooden stampers working on a stone surface, fig. 140. They are raised up by the projecting cogs of a roller, and are then allowed to fall by their own weight.

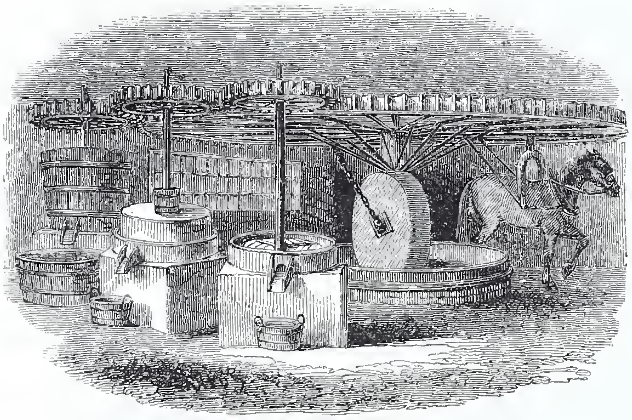
In making up the goods, they have frequently to be measured, an operation which is performed in the very act of folding, by means of the *hooking-frame*, fig. 141, which is a graduated iron bar, supported in a frame of wood, with a sharp projecting needle at one end, and a second needle attached to a piece which slides along the bar and can be fixed at any required distance from the first needle. The girl hangs the cloth upon the hooks in regular folds, until sufficient is collected for a piece, when it is removed from the frame for the purpose of making up.

Making up is a complicated affair, there being at least a hundred different modes of arranging the piece, according to the market for which it is intended ; and also according to the particular country or district whose manufacture has been imitated. Thus there is the *falling-lap*, the *Wigan way*, the *cloth way*, the *Preston way*, and so on. Muslin is made up in *book-folds*, with yellow paper under the first fold to show the pattern, with the corners secured with variegated silk thread. Then there are labels of various sizes and colours in all the languages of the East and of the West, with armorial bearings and devices in gold, bronze, &c. The origin of all this variety is that spirit of competition which leads an enterprising commercial nation to seek out the customers of a rival. Thus France was once distinguished for the excellence of her muslins : when our manufacturers, by dint of skill and enterprise, succeeded in producing muslin equal to that of France, it was not easy to overcome the prejudices of customers in favour of the latter ; so that the dishonest expedient was resorted to of making up after the French fashion, and attaching fac-similes of French labels.

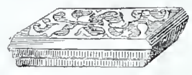
After the making up, the goods are compressed by means of the hydrostatic press, and are then ready for the market.

Colour is imparted to the bleached goods by the ancient art of *dyeing*, which depends for its success upon certain affinities or attractions between different bodies, which have been studied with so much success in modern chemistry. If, for example, a solution of chromate of potash be added to one of acetate of lead, the acetic acid of the latter will leave the lead to unite with the potash ; while the chromic acid will combine with the lead, forming an insoluble precipitate of chromate of lead, or chrome yellow. If a piece of cotton cloth be impregnated with a solution of acetate of lead, and then be passed through a solution of chromate of potash, the precipitate of chrome yellow will be formed within the fibres of the cotton, and it will thus be permanently dyed. The infusions, solutions, &c. of dye stuffs, are made in vats, fig. 143, and the goods are passed many times through the liquor by one of the arrangements shown in the figure. As the goods require to be frequently rinsed, they are passed in and out of water many times by the arrangement shown in fig. 142. When the goods require to be dipped several times, and to be frequently exposed to the action of the air, they are ranged on frames, as in fig. 144, and let down into vats sunk in the floor, or are placed over their mouths to drain.

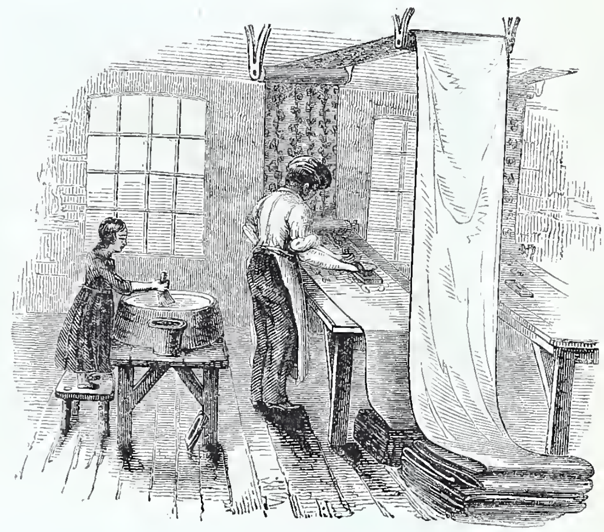
There is a method of dyeing with a *mordant*, which is usually a solution of a metallic salt, which has an affinity for the tissue as well as for the dye stuff. The latter consists of vegetable or animal colouring matters, which are soluble in water, but have not much affinity for the fabric. The mordant, of which common alum is an example, withdraws these colouring matters from solution, and forms with them upon the cloth itself certain compounds, which are insoluble in water. Some dye stuffs, such as indigo, which are not soluble in water, are rendered so by certain chemical actions ; and the cloth being impregnated with the solution, is exposed to the action of the air, which restores the original colour of the dye.



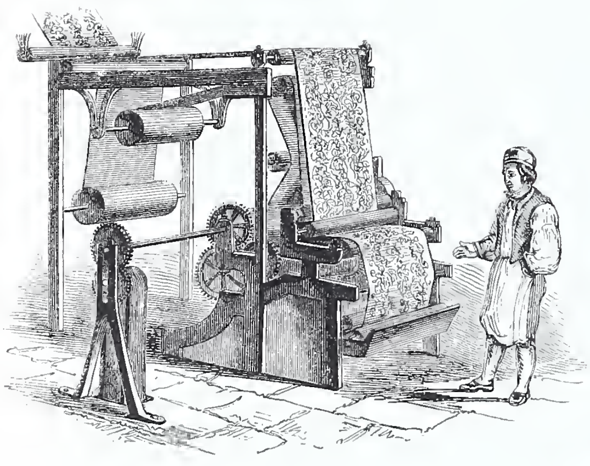
145. COLOUR GRINDING.



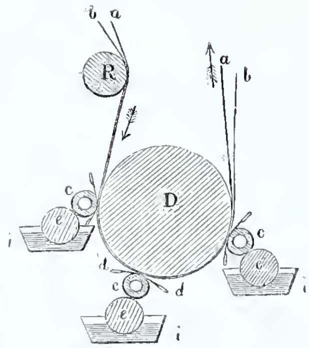
146. PRINTING BLOCK.



147. BLOCK PRINTING.

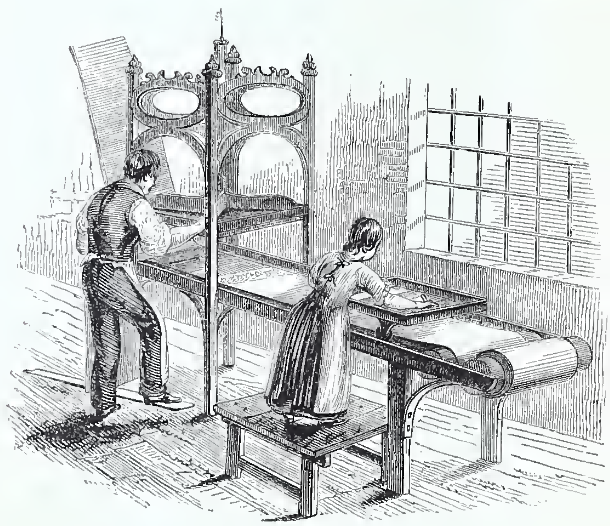


148. CYLINDER PRINTING.



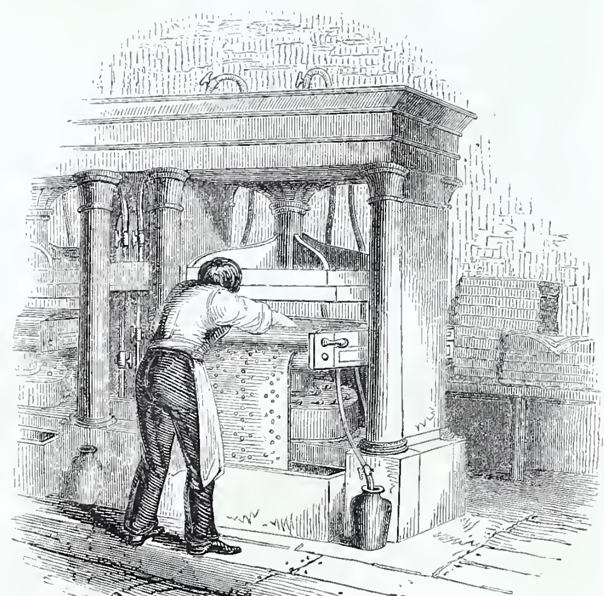
149. WORKING PARTS OF CYLINDER MACHINE.

150. ENGRAVED CYLINDER.

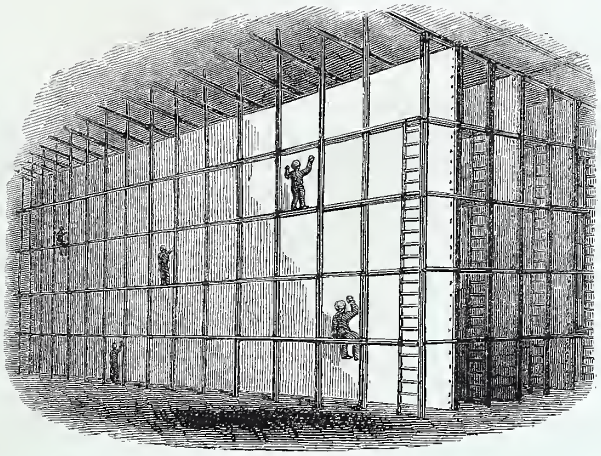


151. PRESS PRINTING.

152. STEAMING.

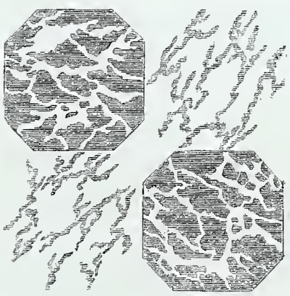


153. BANDANA HANDKERCHIEF-PRESS.

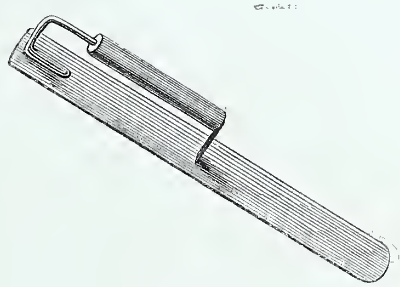


154. THE FRAME-ROOM.

155. TROWEL COLOURING.

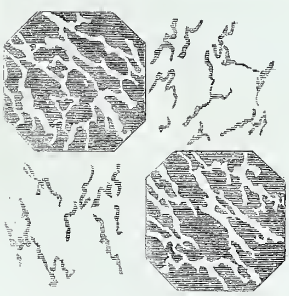


158. FIRST PORTION OF PATTERN.

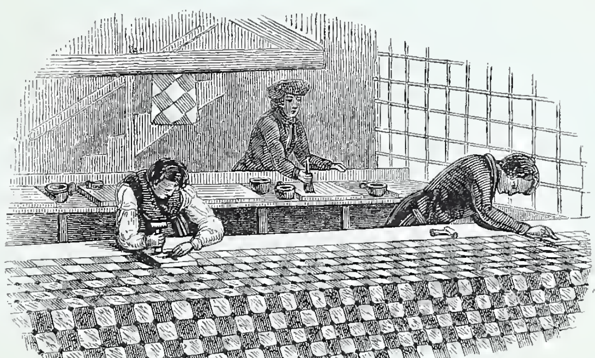


156. TROWEL.

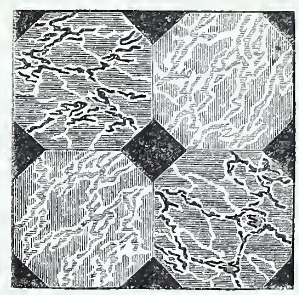
160. THIRD PORTION OF PATTERN.



159. SECOND PORTION OF PATTERN.

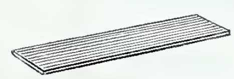


157. PRINTING.

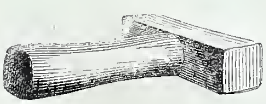


161. COMPLETE PATTERN.

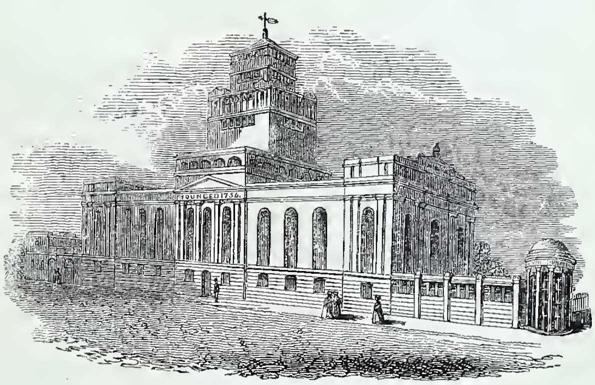
162. BRUSH.



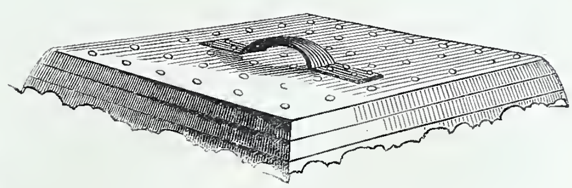
164. SCRAPER.



163. MALLET.



166. FLOOR-CLOTH FACTORY AT KNIGHTSBRIDGE.



165. PRINTING BLOCK.

VIII.—CALICO-PRINTING.

THE art of producing a coloured pattern on cloth is of ancient date; since the love of ornament is a natural propensity, and all that civilisation does is to correct and refine it, and bring it within the principles of good taste. The town of *Calicut*, in the province of Malabar, originated our word *Calico*, and in that town the art of calico-printing was at one time carried on extensively. The large cotton-chintz counterpanes, called *Pallampoors*, are still occasionally met with, as specimens of Indian skill; the pattern being made out by impregnating certain portions of the fabric with wax, and then allowing certain dye-stuffs to act on the remaining portions. In Great Britain, the art of calico-printing has been one of successive improvement, both with respect to machinery and chemical applications; and also a constant struggle with the Excise to get rid of the duty on printed goods, which limited the consumption, and in many ways retarded the progress of improvement in the manufacture.

The simplest method of producing a pattern on calico (we speak of calico as a generic term, since linen, worsted, and mixed cloths are equally adapted to the process of printing) is by means of a wooden block, on the face of which the design is engraved in relief (fig. 146). The block varies from nine to twelve inches by from four to seven inches, and has a handle at the back. This block is charged with colour by pressing it upon a piece of woollen cloth, stretched tightly over a wooden drum, called the *sieve*, and floating in a tub of size, so as to form a kind of water-pad. A child called the *tearer* covers the sieve with colour, and keeps it uniformly distributed by means of a brush (fig. 147). The calico is printed at a long table, several pieces being joined end to end, and lapped round the roller, or arranged in folds, as in fig. 147. In order that the colour may dry, the cloth is passed over hanging rollers, so as to expose a large surface to the air. The printing-table is covered with a blanket; and the block being charged with colour, and applied to the calico, the impression is transferred by striking the back of the block with a wooden mallet. By repeated applications of the block to the sieve and to the calico, the surface of the latter is covered with a pattern in one colour. If the pattern be in several colours, there must be as many blocks as there are colours, and a distinct sieve for each colour. But when the design consists of straight parallel lines of different colours, they may be applied by one block at a single impression, by arranging the colours in small parallel tin troughs, and taking up a portion of each colour with a kind of wire brush, whence it is transferred to a peculiarly-arranged sieve, which supplies the block.

The greatest improvement in this art was the invention of *cylinder* or *roller printing;* which bears the same relation to block-printing as letter-press printing by steam does to the old hand-press. The cylinder machine will produce as much work in three or four minutes as can be accomplished by block-printing in six hours. The appearance of the cylinder machine will be understood by reference to fig. 148, while its working parts are represented in fig. 149. This machine is arranged for printing in three colours; *e* is a cylinder or roller (shown separately in fig. 150), mounted so as to revolve against two other cylinders, *D*, *e;* the cylinder *e* is covered with woollen cloth and dips into a trough, *i*, containing the thickened colouring matter. When the roller *e* revolves, it takes up a coating of colour, and distributes it over the cylinder, *e;* but as the colour is wanted only in the engraved parts of the cylinder, the excess of colour is scraped off the cylinder as it revolves, by means of a sharp-edged knife, or steel edge, *d*, called *the doctor*. The large drum, *D*, is covered with an endless web of blanketing, *a*, which travels in the direction of the arrows, accompanied by the calico, *b*, *b*, which is to be printed, and which moves between it and the engraved cylinders. In this way, it will be seen, that as *D* revolves the calico travels between the blanket and the cylinders, and receives from each cylinder its share in the pattern in one colour; and if these cylinders are properly arranged, the different parts of the pattern will fall into their places and blend into one harmonious whole. The doctor is so arranged that the colour scraped off shall fall back into the trough, *i*. There are usually two doctors to each cylinder, one called the *colour doctor*, and the other, *d'*, the *lint doctor;* the office of the latter being to remove the fibres which the roller acquires from the calico. The calico, as it leaves the machine, is conducted through a hot room, for the purpose of being dried. As many as eight colours may be printed at one operation. Of course, as the number of colours is increased, the difficulty of adjustment, so as to make each colour fall into its proper place, increases also.

Press-printing, fig. 151, is a refinement on ordinary block-printing. The block containing the pattern is, in this case, about $2\frac{1}{2}$ feet square, and is so arranged in a frame, with its face downwards, that it can be raised and lowered at pleasure. The colour is supplied by means of a trough moving on wheels; so that it can be run under the block, which, being let down for its supply of colour, and again raised, the colour-trough is run out, and the block is brought down upon the calico. Striped patterns are produced in this way with much effect.

There are other mechanical modes of calico-printing; but the chemical arrangements are of a more complicated character. The preparation and application of the colours involve a large amount of scientific knowledge. Mordants are in constant use, and these and the colours must be mixed with proper *thickeners*, such as starch, gum, and other substances. A due exposure of the goods to the air after the printing, is called *ageing;* and this requires experience, as does also the proper method of removing the superfluous mordant and other colours, by washing in suitable solutions. In many cases, to produce fast colours, the printed goods require to be exposed to the action of steam; for which purpose they are rolled round a perforated cylinder, put under cover, as in fig. 152, and steam is blown through the cylinder. In some cases effects are produced by printing with a *resist paste*, the object of which is to prevent those portions of the cloth, covered with the resist, from acquiring colour when the calico is passed through the dye-beck. The paste being removed, we have the effect of a white design on a coloured ground; then again we have what is called the *discharge style*, where the goods being dyed, are arranged in a hydrostatic press, as in fig. 153, covered with perforated metal plates; and strong pressure being applied, a solution of chloride of lime, or of some other substance which acts as a discharger, is allowed to percolate through, and the colour is removed immediately below the perforations. Then, there is the *padding style*, applicable to mineral colours; where the cloth is passed through a padding machine, which is similar to the starching-machine, fig. 137, only the trough contains the thickened colour instead of starch. To produce a design in a mineral colouring matter, the cloth may be printed in one solution, and padded in the other.

The designs for calico-printing give constant employment to a class of artists known as *pattern designers*. In this branch of art there is abundant opportunity for the display of good taste, which is the more likely to be exercised and cultivated in proportion as the consumer of printed goods possesses it herself. Since the date of the Great Exhibition, our designers have greatly improved, and we are not now so dependent as we formerly were on French artists for our display of spring goods, which light up the windows of the linendraper.

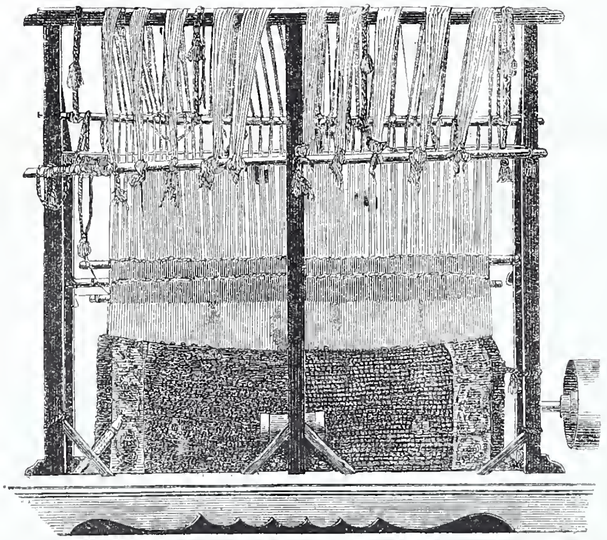
IX.—FLOOR-CLOTH.

A FLOOR-CLOTH is a specimen of a rude kind of calico-printing, and may be appropriately described in this place. The cloth or canvas which forms the basis of floor-cloth is woven in widths of from 18 to 24 feet, so that there may be no seam. The looms are adapted to this great width, and the shuttle is thrown backwards and forwards by two men, one on each side the room. The warp is upwards of 100 yards in length, and the canvas is of the fineness expressed by sixteen or eighteen threads to the inch. It is manufactured at Dundee, and the neighbourhood. When the bales are received at the floor-cloth factory, a piece of canvas of the required size is wound upon a wooden roller and removed to the *frame-room*, which contains a number of stout open frames, each furnished with scaffolding. Here the roller is set up on end, and the lower end is placed upon a low carriage and moved alongside the frame to which the canvas is attached by nailing the edge to an upright post, and to the top by means of hooks. The other upright edge of the canvas is similarly attached to another upright post, and it is made tight by screwing out the frame, whilst the top and bottom edge are secured to beams which can be turned round so as to tighten the canvas in a vertical direction. Each surface of the canvas may thus present an area of from 1400 to 1800 square feet. It is prepared for the reception of the paint by a coating of size, and by being well rubbed with pumice-stone, commencing from the top of the canvas, fig. 154. The paint is applied in dabs with a short thick brush, and is spread by means of an elastic steel trowel (fig. 156), about two feet long, and used with considerable force. The man then holds the trowel obliquely, so that its edge may lay bare the high threads of the canvas (fig. 155), while the channels between the threads are completely filled up. This first coat of paint, called the *trowel-colour*, is left to dry during ten or fourteen days; the surface is then sized and pumiced, and a second thinner coat is laid on with a trowel. This forms the back or under side of the floor-cloth. Three coats of trowel-colour are then laid on the face, and a fourth, or *brush-colour*, by means of a brush. This forms the ground of the pattern. The addition of the paint to the canvas has increased its weight fourfold: it is now cut away from the vertical posts, and also from the bottom, and is wound upon a roller from the bottom upwards, with the face inwards, and a quantity of paper is rolled up with it to prevent the surfaces of the coil from adhering. The roll is then hauled up into the printing-room. The pattern is impressed by means of blocks (fig. 165) of about 18 inches square, and 2½ inches thick, by a process almost identical with that already described for printing calico by hand, a separate block being required for each colour; the three blocks, figs. 158, 159, 160, being required to make out the complete pattern, fig. 161. The roller containing the floor-cloth which is to be printed is supported on its two extremities under the printing-table. A portion is unwound upon the table, the surface is slightly roughened with a steel scraper (fig. 164), then rubbed with a brush (fig. 162), after which the block (fig. 158) is pressed upon the colour-sieve and transferred to the cloth, the impression being made distinct by striking the back of the block with the handle of the mallet, fig. 163. After the first printer has proceeded a little way, a second printer with the block (fig. 159) goes over the same ground, while a third printer with a block (fig. 160) follows the second. Each printer has his own colour-sieve, and a boy serves as a tearer to all three. Fig. 157 represents the proceedings of all four workmen. As the printing proceeds, the finished portion is turned over the table to dry in the air, some months being required for the purpose.

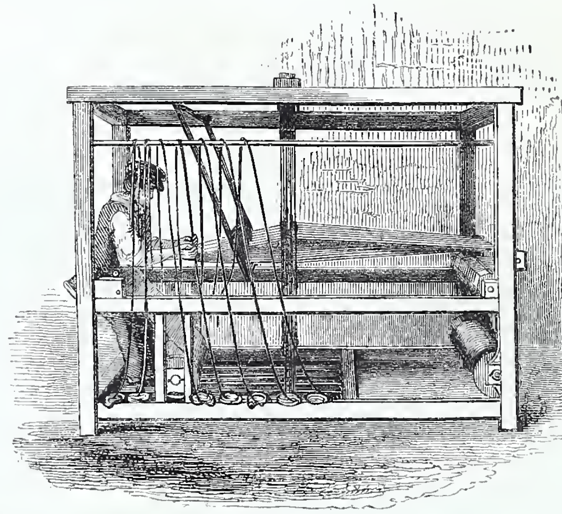
The grinding and preparation of colours is an important part of the business of the calico-printer, and of the floor-cloth manufacturer. Some of the coarser colours are crushed by means of the *edge-wheel*, shown in fig. 145; while others are ground with oil between mill-stones, as represented in the same engraving.

The patterns for floor-cloths should not be elaborate, but should rather follow the laws which regulate mosaics, marble pavements, and inlays for floors. What are called *all-over* patterns, of simple geometrical diapers in quiet, graduated tints, have the best effect; but where the work is large, frets and guilloches may be employed for borders, and a centre may be made out with geometrical combinations.

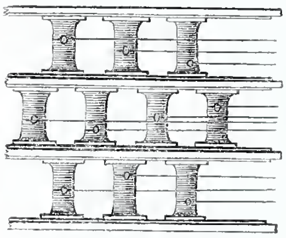
The buildings required in this manufacture are extensive, and some of them have pretensions of an architectural character, such as the factory of Messrs. Smith and Baber, represented at fig. 166.



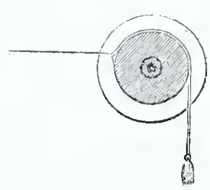
167. HINDOO CARPET LOOM.



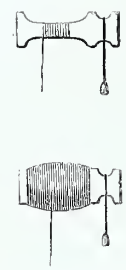
168. RUG LOOM.



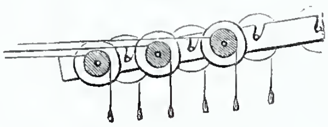
171. PORTION OF BOBBIN-FRAME.



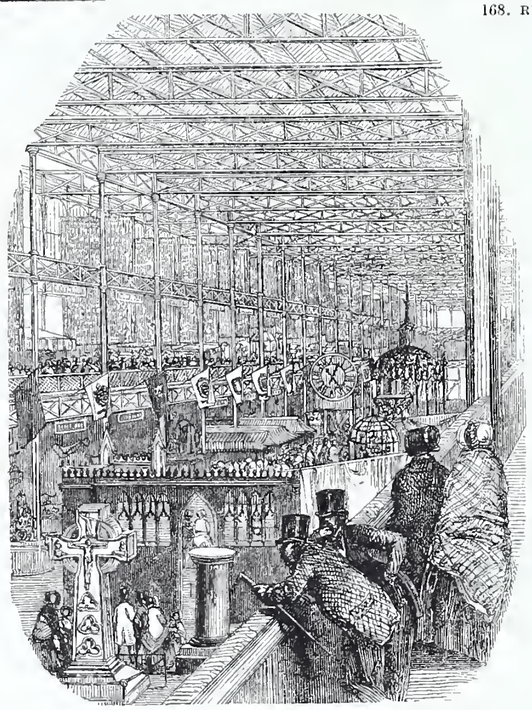
173. BOBBIN.



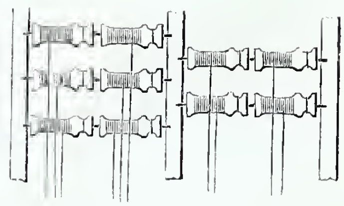
171. BOBBINS.



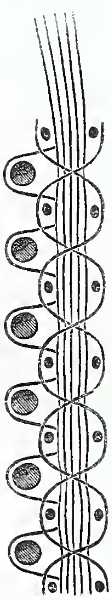
172. SIDE VIEW OF 171.



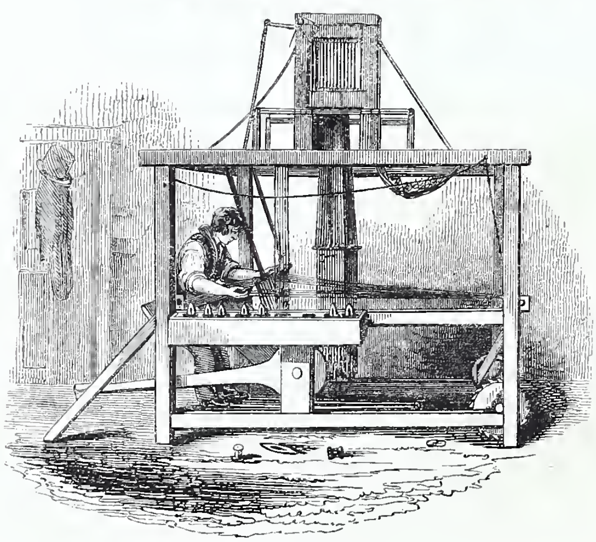
169. ARRANGEMENT OF CARPETS AT THE GREAT EXHIBITION.



175. ARRANGEMENT OF BOBBINS.



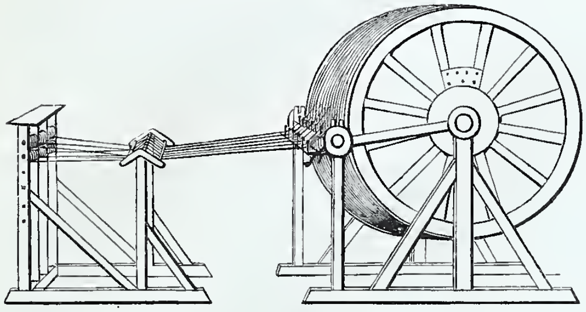
176. STRUCTURE OF BRUSSELS CARPET.



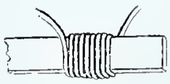
170. KIDDERMINSTER OR SCOTCH CARPET LOOM.

177. STRUCTURE OF WILTON CARPET.

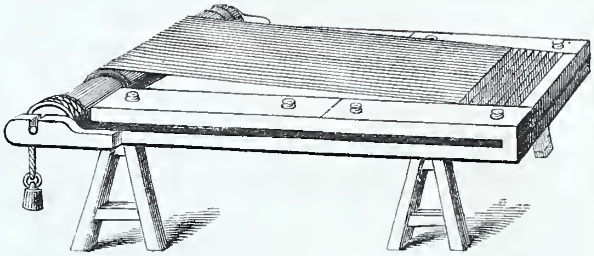
178. WIRES.



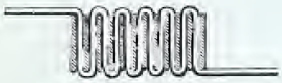
179. YARN-DRUM.



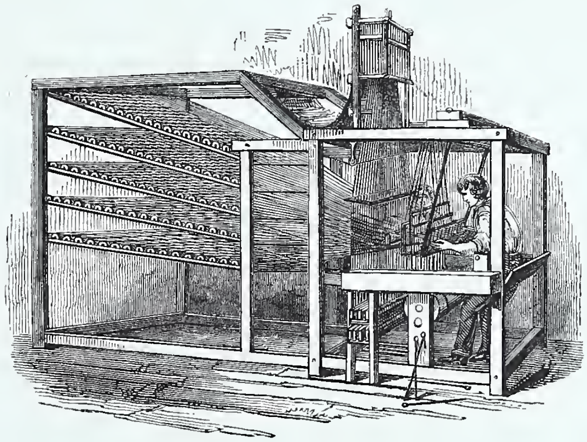
180. STRIP.



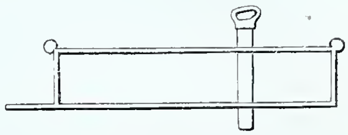
181. BEAM AND FRAME.



182. COILED-UP WARP.

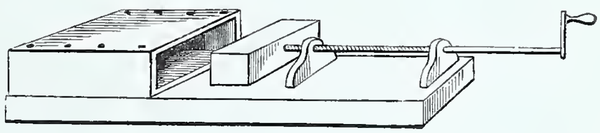


183. BRUSSELS CARPET LOOM.

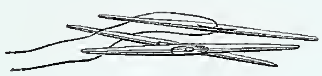


184. KNIFE AND GUIDE.

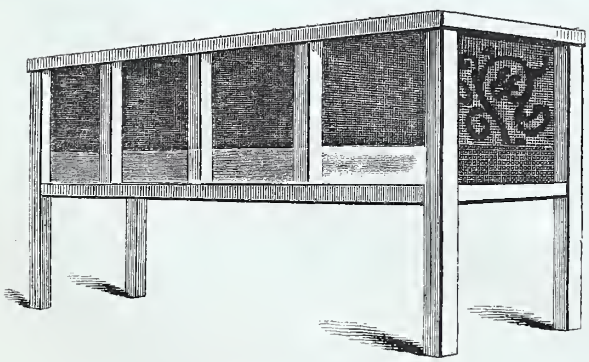
185. CLAMP.



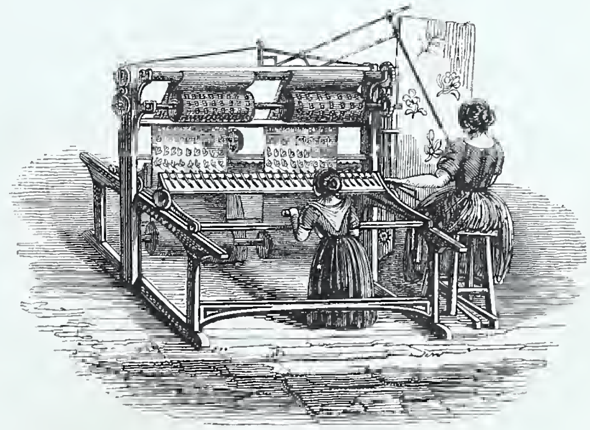
186. YARN-CASE.



187. EMBROIDERY NEEDLES.



188. WARP FRAME.



189. EMBROIDERING MACHINE.

X.—CARPETS.

In former times the floors of houses were covered with rushes, straw, or hay; but as civilisation advanced, such rude materials could not be tolerated. Nature, which is beautiful in all ages, and among all people, suggested a substitute in the exquisite covering of the earth; and, accordingly, we find that the earliest carpets were a coarse web of one colour. As men acquired a taste for the beautiful, the flowers which adorn the turf suggested a method of ornamenting carpets. The patterns became more and more elaborate, until at length the whole contents of the flower-garden appeared to be concentrated on the floor of a single room. Had men continued to adorn carpets with such natural objects as occupy the ground, the art of ornamentation would have been properly exercised; but the artists of the floor, wishing to rival the artists of the walls, threw into their designs landscapes, buildings, architectural scrolls, reversed groinings, and perforated tracery, forgetting the broad principle of propriety, which would not represent on the floor objects which, if actually present, would be ridiculous and inconvenient. In carpets a *flat* mode of treatment ought to prevail. The colours ought to be quiet, and the pattern should not be so strongly marked as to mar the effect of the furniture, or of the wall decorations of the room. The display of carpets at the Great Exhibition of 1851 (fig. 169) was rather remarkable for excellence of workmanship than taste in design.

The earliest carpets were in the form of rugs. The Hindoo loom (fig. 167) represents the warp stretched in a vertical direction, resembling in some respects the loom by which the Turkey carpet is produced. The Turkey loom consists of two upright pieces of wood, supporting a beam or roller at the top, upon which the warp or *chain* is wound, while another beam near the floor receives the carpet as it is made. The weaver, having thrown a weft thread once or twice across, fastens to every thread of the warp a small bunch of coloured worsted yarn, varying the colour according to a pattern before him. One row being completed, he passes a linen weft through the web and drives it well up, in order to hold the small bunches or tufts securely: another row of bunches is then added, and in this way a stout carpet is made in separate breadths, which, on being joined together, form one large carpet. Rugs are produced by a similar method, the warp or chain being laid horizontally, as in the common loom. Fig. 168 represents a rug-loom: the coloured worsted yarns are hung over a bar to the right of the weaver, who, taking the end of one of the bunches of yarn, attaches it to the chain, cuts it off at the proper length, then twists in another, which he severs in like manner, and so on until a row across the warp is completed, when he passes a shoot or two of weft, and drives up the batten with considerable force.

The *Kidderminster* or *Scotch* carpet is formed with a worsted chain and a woollen shoot. It consists of two distinct webs, incorporated into one another in such a way as to produce the pattern: each web or cloth is perfect in itself, so that if one were carefully cut away the other would be like a very coarse baize. Both these webs are woven at the same time, and each is brought up to the surface as the pattern requires it at any particular part. A full colour is obtained by making the weft cross a warp of the same colour; thus, to produce a full red, red warp must be crossed by red weft; but in general the warp is not much varied, the variety of colouring being produced by the weft. The weaver is therefore furnished with shuttles of differently coloured wefts, as shown in fig. 170. Any particular colour can be concealed by sending the threads to the other web, so that a *two-ply* Kidderminster, as it is called, has a *right* and a *wrong* side. If, for example, the colours were green and red, the green portions on one side would be red on the other, and *vice versâ*. The apparatus for regulating the pattern is mounted on the top of the loom, and is worked by the method already described for the Jacquard apparatus (fig. 107).

The *Brussels* carpet has a linen web, which incloses worsted yarns of different colours, raised into loops as they are required to form the pattern. Fig. 176 shows the structure of Brussels carpet; the small black dots show the ends of the shoot, and the double waving lines two separate sets of linen warp or chain. Between the black dots, that is, between the upper and the under shoot, is the worsted yarn, usually consisting of five *ends*, all of different colours. But each end may consist of one, two, or three threads, according to the quality of the carpet. Supposing there are two threads to each end, there will thus be ten threads bound into the carpet every time the warp is shed. In forming the pattern, all that is necessary is to bring to the surface at any particular spot such of the five coloured yarns as are required, and by turning them over wires, represented by the large shaded dots in fig. 176, to form them into loops, which project permanently above the surface when the wires are withdrawn. As the coloured threads are taken up very unequally, they cannot be wound upon a beam, but have to be placed each upon a bobbin by itself. The bobbins are arranged in frames at the back of the loom, fig. 183, and each bobbin is furnished with a leaden weight, for the purpose of keeping the worsted slightly stretched. Portions of the frames, with the bobbins, weights, &c., are represented separately in figs. 171 to 175. There are as many frames in the loom as there are colours in the carpet, and the number of bobbins in each frame is regulated by the width of the carpet. The usual three-quarter width requires 260 bobbins to each frame, or 344 if the width be four-quarters. The ends are carried from each bobbin through small brass eyes, called *males* or *mails*, attached to fine cords, each cord being passed over a pulley fixed above the loom, and brought down again by the side of the loom and fastened to a stick. For a three-quarter carpet there are 300 males, cords, and pulleys. The pattern is made out by a Jacquard or some other arrangement; but it must be remembered that when the ends are raised a round wire is placed into the shed, one of the treadles is then depressed, whereby one of the linen warps is raised, while the other warp, with all the remaining worsted ends, is depressed. The shuttle with a linen shoot is then thrown in, the weaver next depresses the other treadle, by which means the worsted and the warp before depressed are now raised; and then throws in a second or undershoot, striking each time with a heavy batten, so as to force the materials closely together and give solidity to the work. In this way a wire is woven in; and when a sufficient number of wires have thus been inserted, some of the earlier ones are pulled up by inserting a hook into a bow formed at the end of each wire.

The *Wilton* carpet differs from the Brussels in the form of the wire and the method of removing it from the loops. The wire has a groove in the upper surface, as in one of the forms shown in fig. 178; and instead of being drawn out, it is cut out by drawing a small knife furnished with a guide, and called a *travat*, along the groove. The worsted loops thus cut form a pile or velvet, the structure of which will be seen in fig. 177. By increasing the dimensions of the wire, the Wilton carpet can be made of any thickness or quality. The quality is measured by the number of wires to the inch, the usual number being nine for Brussels, and ten for Wilton. The Wilton carpet is finished by passing it through a brushing machine, and shearing it level by means of a broad perpetual, fig. 129.

There are other varieties of carpet: such as the *Axminster*, which is similar to the Turkey; the *Venetian*, which is made for staircases and passages; the *Scotch*, which is identical with the

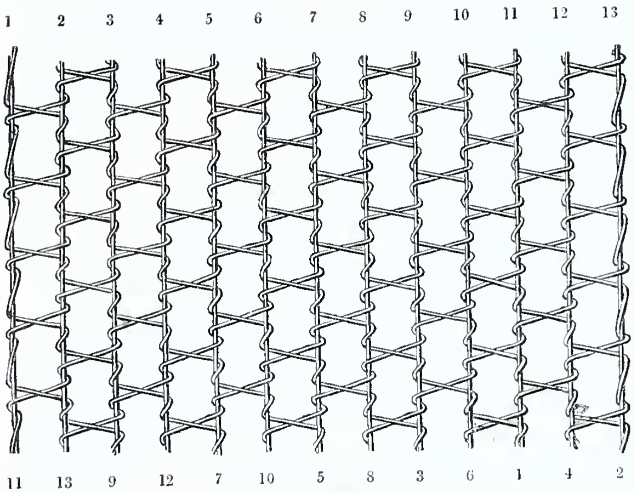
Kidderminster; and there is also the *Three-ply* or *Triple Ingrain* carpet, which resembles the Kidderminster, only it has three webs instead of two.

Several improvements have been introduced of late years into the carpet manufacture. We have seen that in the Brussels carpet five sets of coloured yarns are employed; while only one set can appear at the surface at any particular spot, the other four being concealed in the web. It occurred to Mr. Whytock that if, instead of five coloured yarns, he were to employ one yarn, dyed of the requisite colour at different places, he would be able to get rid of the complicated apparatus for producing the pattern; and the web could be made with only one body worked like a simple velvet. The warp thread would then have to be dyed by a special arrangement, represented in fig. 179, where the yarn is wound in regular coils round the circumference of a large drum, and the dye is applied by means of rollers working each in its own colour-trough, moving in a carriage; and being brought up to the drum, a coloured streak is communicated across it, in such a way that, on unwinding the yarn, a coloured mark would be situated at equal distances along the length of the yarn. The cylinder is then turned round through a space equal to the breadth of the impression left by the colour-roller, and another streak of colour is applied; and in this way the cylinder is completely covered with colours which succeed each other according to the pattern. The yarns are then removed from the cylinder, the colours are fixed by steaming, and the yarns are wound upon bobbins; and when a sufficient number have been collected, they are arranged side by side, so as to form the warp. The arrangement of the colours on the cylinder, and side by side in the warp, is a simple matter of calculation, assisted by design or pattern papers. Before commencing to stamp the colours on the cylinder, a narrow black line is made across the yarns as a common starting-point; and, in arranging the warp, the yarns are held by means of a clamp, fig. 185, at this black line, which is advanced along the yarns as the pattern is repeated. The weaving is then conducted in the usual manner for plain weaving. There is a method of making carpets, rugs, &c., without any weaving at all, but simply by cementing a nap or pile to plain cloth; for which purpose the yarns are warped upon a beam, fig. 181, which is supported at one end of a frame, and weighted with friction cords and weights, in order to keep the yarns properly stretched, the ends of which are attached to the front rail of the frame. The workman then takes a number of strips of metal, and places one under the warp, close to the front rail, and parallel therewith; inserting the ends into grooves made for the purpose in the sides. He then places a second strip edgeways, like the first, upon the upper surface of the warp, depressing the threads evenly between the two strips, and inserting the ends of the second strip into side grooves as before. The third strip is put under the warp, the fourth upon the warp; and in this way he proceeds until a quantity of warp is coiled up, as in fig. 182. The surface of this arrangement being combed or carded out, and pressed down evenly, a coat of fluid india-rubber or other cement is spread over it, and then some coarse cloth is applied to form a back to the carpet or rug. When this is dry, the frame may be turned over, and the several folds of yarn be cut, so as to liberate the metal strips; and in this way a beautifully soft nap or pile is produced.

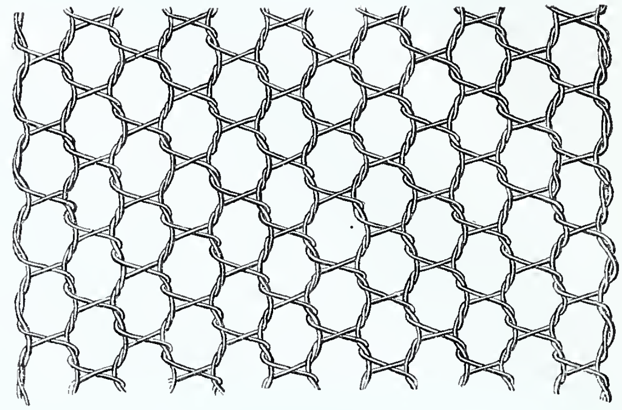
By a variation in the arrangements, ornamented carpets and rugs may be produced by this cementing process. A number of four-sided frames of canvas or of perforated zinc are fixed upright in a frame, as in fig. 188. The person who works the design has the pattern on paper, or it may be sketched upon the canvas itself. Being furnished with as many yarns as there are colours or shades of colour, he begins by drawing with a needle a yarn through a hole or mesh in the canvas at one end, carrying it through the other frames and out at a corresponding hole in the last frame. By continuing this operation, all the holes are filled with their appropriate yarns. The mass of yarns thus collected is inclosed in a case open at both ends (fig. 186), and there is a solid ram or piston fitting into one end, for the purpose of forcing out portions of yarn as they are required. India-rubber or other cement being applied to the ends of the yarn, and this being covered with coarse cloth or canvas, a certain portion is cut off by means of the knife and guide, fig. 184; a fresh portion is pressed out of the case by means of the ram, and the process is repeated until the whole length of yarn is thus disposed of. When the two outer frames (fig. 188) have been five feet apart, as many as 480 copies of the same article have been produced.

A still simpler method of forming a napped surface is shown in fig. 180. The warp is wound round a thin strip of metal; and a number of strips, similarly covered, being packed side by side in a frame, some coarse fabric is cemented to the top, and the strips are afterwards cut out.

The figured cloths used for covering the walls of apartments, and included under the term *tapestry*, ought to include a style of decoration essentially distinct from that of carpets. Figures, landscapes, and ornamental devices may properly belong to tapestry, however much we object to the production of such forms in worsted or needlework. The word tapestry is from the French *tapis*, and this is from the Latin *tapetum*, which is identical with the Greek *tapes*, or *tapis*. The original meaning of the word was a covering for a bed, or a couch; and the French word, though generally applied to carpets, is also used to express other figured cloths used as coverings. Many of these figured cloths, in which the decorations were inserted by the needle, are now done by means of an embroidering machine, fig. 189. It is useful where the same ornament has to be repeated many times on the same fabric; and it enables a female to embroider a design with upwards of one hundred needles almost as easily as with one. The cloth is suspended in a vertical position, and the needles, furnished with the proper threads, and pointed at both ends, the eye being in the middle, as in fig. 187, are held by pincers in a frame, mounted in a carriage, which is wheeled up to the suspended cloth: this is pierced by all the needles, which, on passing through, are seized on the other side by the pincers of a second frame. On drawing this away from the cloth, the needles will be drawn through it together with the threads; and on moving the second frame up to the cloth, the needles will pass through in an opposite direction, and be clipped and drawn through by the first frame. During these motions of the two frames backwards and forwards, the frame in which the cloth is suspended is moved in a regulated order, by means of a lever attached to a pantagraph; and by moving this lever over the points of an enlarged pattern, the cloth is slightly shifted at each motion, and the pattern is repeated thereon, on a small scale, by the passage of the needles.



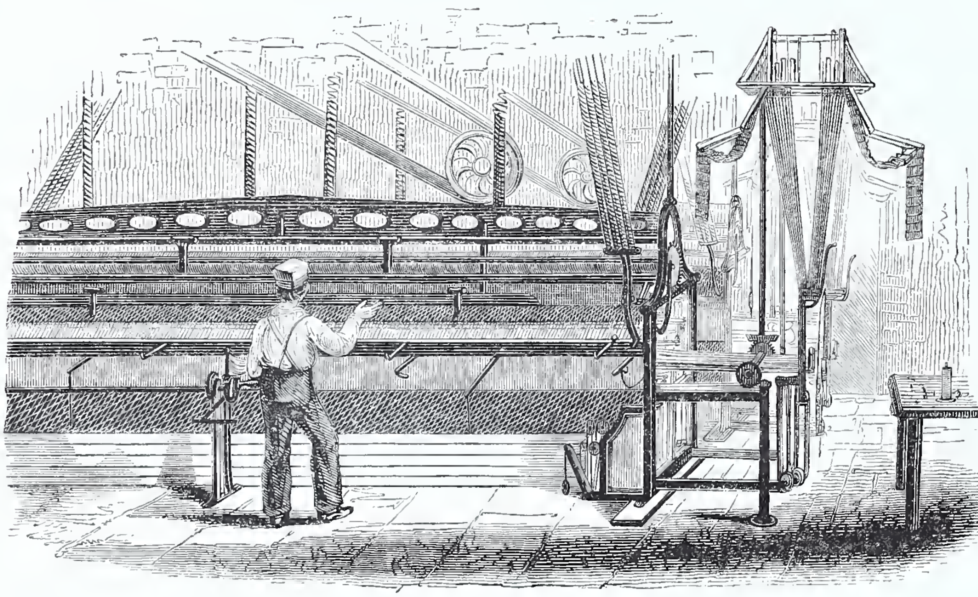
190. ILLUSTRATIONS OF LACE.



191. SPECIMEN OF LACE (*Magnified*).

192. PLAIN WEAVING.

193. TWILLED WEAVING.

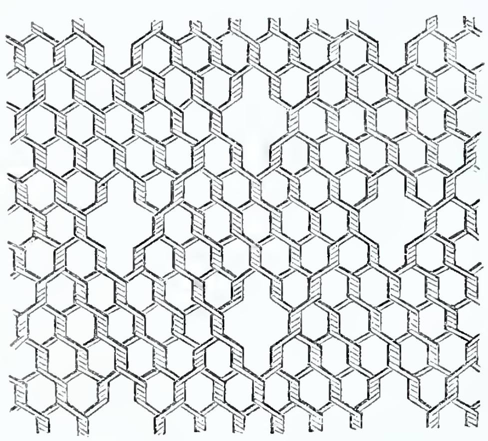


196. BOBBIN-NET MACHINE.

194. STRUCTURE OF GAUZE.

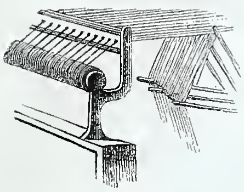
195. STRUCTURE OF LACE.

197. PILLOW LACE MAKING.

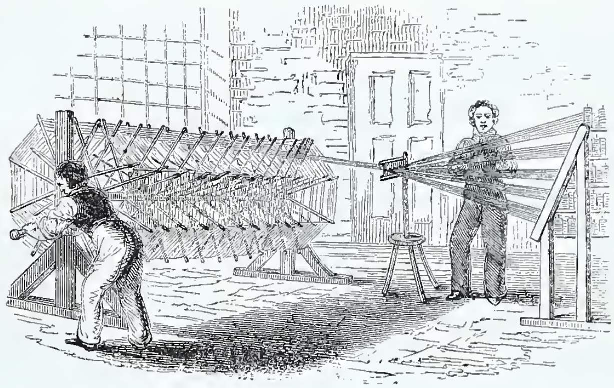


198. SPECIMEN OF LACE (*Magnified*).

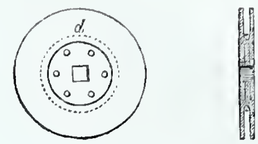
199. FILLING THE BOBBINS.



201. THREAD-BEAM.

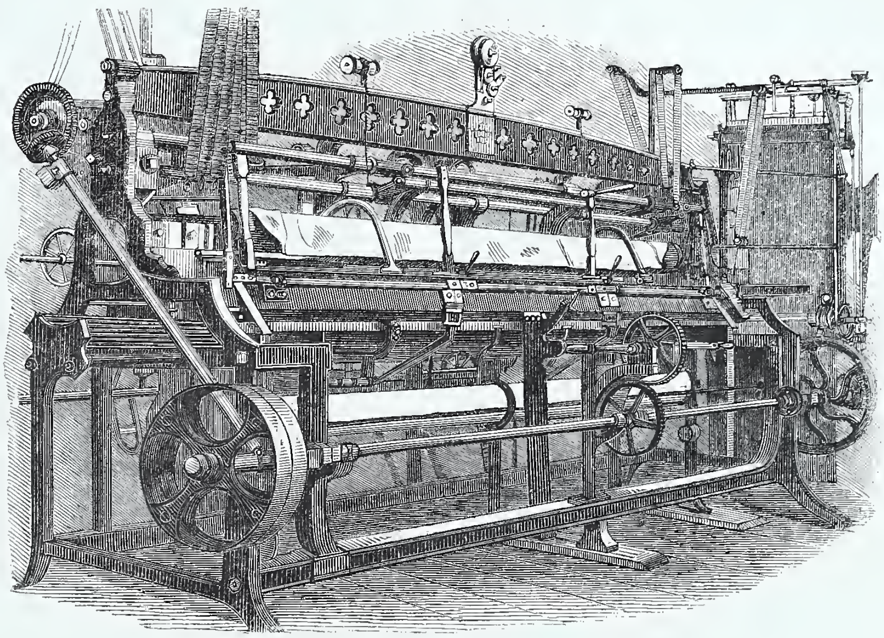


200. WARPING.



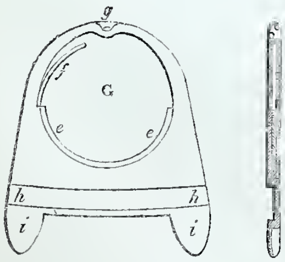
202. WEFT BOBBIN.

206. NEEDLE.

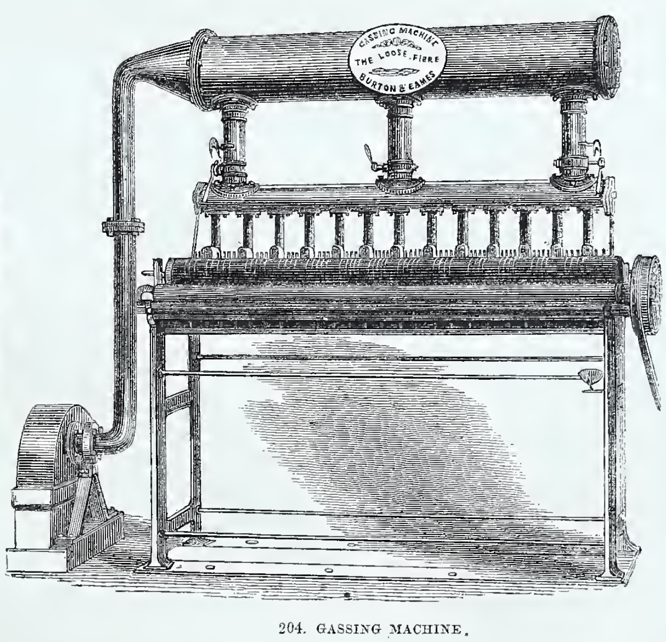


203. BOBBIN-NET MACHINE SHOWN AT THE GREAT EXHIBITION.

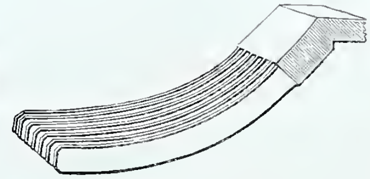
207. POINT.



205. BOBBIN-CARRIAGE.



204. GASSING MACHINE.



208. PORTION OF COMB.

XI.—LACE.

The delicate fabric known as *lace* (a word said to be derived from the Latin *lacinia*, the guard-hem or fringe of a garment) was formerly made of such costly materials, and at so slow a rate, as to be one of the distinguishing articles in the dress of a wealthy or noble person. Nor was its use confined to the fair sex, as we see by the portraits, by Vandyke and other eminent artists, of the princes and nobles of the seventeenth century; and so much pains has the artist taken with this article of dress, that it is easy to name the variety so faithfully copied. Thus, in the pictures by Sir Peter Lely and Sir Godfrey Kneller, the *Brussels Point* is the favourite variety, in which the net-work is produced by bone bobbins on a pillow, while the pattern is afterwards worked in with a needle.

The difference between weaving and lace-making will be seen by reference to figs. 192 to 195. Fig. 192 represents *plain weaving*, and fig. 193 *twilled weaving*, which have been already explained. Fig. 194 represents the structure of *gauze;* in which, after every cast of the shuttle, the warp threads are made to cross each other, whereby the weft threads represented by the black dots are separated, and a firm but transparent texture is produced. In fig. 195, the threads of the weft are twisted round those of the warp, which twisting is the distinguishing feature of lace-making.

If we examine a piece of lace, it will be seen, that while a series of warp threads proceed in one direction, nearly parallel to each other, as in plain weaving, the weft threads are inserted differently. Each weft thread, fig. 190, twists once round each warp thread, until it reaches the outermost one, when it makes two turns; proceeding, after the second turn, towards the other border, in a reverse direction. By means of this double twist, and the return of the weft threads, the selvage is formed. The twisting and interlacing of the threads produce six-sided meshes, as in figs. 191, 198.

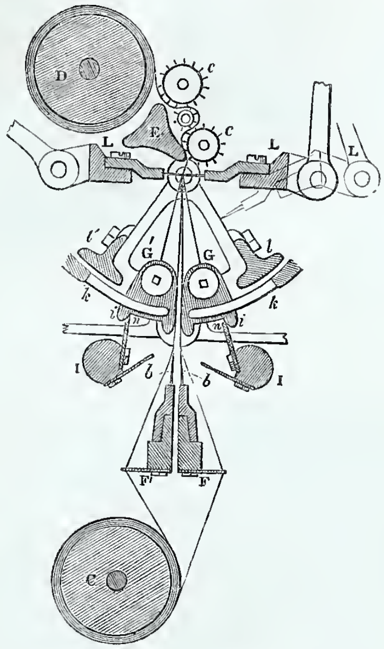
Pillow or *bobbin-lace*, the original manufacture, is made on a hard stuffed pillow or cushion, previously covered with the pattern drawn out on a piece of parchment, fig. 197. The threads are wound upon bobbins, and, in order to form the meshes, pins are stuck into the cushion, and the threads are twisted round them. The pattern on the parchment indicates where these pins are to be inserted, and also gives a design for the gimp or thicker thread, which is so interwoven within the meshes as to form flowers, curves, &c. The bobbins hang down by their threads on different sides of the cushion; and the lace-maker, with a pair in each hand, twists them in such a manner as to form the sides of the mesh. The lace made by hand is distinguished by such terms as *Honiton*, and *Thread* or *Pillow*-lace; also *British Point*, *Tambour*, and *Limerick* laces. Some descriptions of lace are made with pure handspun linen thread, worth from 100*l.* to 120*l.* sterling per lb. France is eminently a lace-making country; and the manufacture extends over a large part of that country; each district having its peculiar style, which is immediately recognised by good judges, although the mode of manufacture and the material may be the same in several districts. The seats of manufacture give names to the different varieties, such as *Point d'Alençon*, *Lisle*, &c. Belgium is also eminent for laces, which include the four great varieties of *Brussels*, *Mechlin*, *Valenciennes*, and *Grammont*, each of which has many varieties.

Where the chief cost of an article arises from the large amount of manual labour bestowed on its production, attempts would naturally be made to produce it by self-acting machinery; especially where the article is a beautiful object of dress, for that presents irresistible attractions to all classes. The origin and progress of lace-making machines would form a very curious chapter in the history of invention. There is the usual opposition to the introduction of any kind of machinery; there is the usual kind of perseverance, privation, and distress on the part of inventors, who are more numerous in this department of the useful arts than in almost any other with which we are acquainted. There is the usual failure of the many, and the marked success of the few. At one time, men were so bent on making meshes by machinery, that they could think of nothing else, and talk of nothing else; and, when sitting down to enjoy a little leisure, they would be seen, with serious face and knitted brow, moving strings about upon their fingers, and passing the combination from hand to hand as if they were playing at grown-up "cat's cradle." The production of a lace-making machine thus grew into a passion, a monomania, and many men ended their lives in a lunatic asylum. This is a common story with inventors, who, often without a spark of mechanical genius, set themselves to work to solve problems which can be grappled only by the highest constructive skill aided by a knowledge of theoretical science; and even then the finished machine is often but the result of a long series of minor improvements grafted on to the first crude idea.

The lace-making machine is complicated; but we will endeavour to give a clear idea of the principle of one variety known as the *bobbin-net machine*, figs. 196 and 203. But first as to the preparatory processes. The thread is wound upon a roller for the warp, and upon bobbins for the weft. The warp threads are wound upon a reel, fig. 200, and thence transferred to a roller or *thread-beam*, which extends the whole length of the lace frame. The weft threads are wound upon small bobbins, seen in front and in section, fig. 202. Each bobbin consists of two thin brass disks, with a hollow in the middle of each, and riveted together so as to leave a circular groove between them for the thread. In the centre is a square hole, through which is passed a square spindle, to facilitate the winding. One or two hundred bobbins being thus spitted, the thread is passed from the drum, fig. 199, through slits in a brass plate to the bobbins; and, as the rod is turned round, the drum revolves and delivers its thread to the bobbins, while a hand, moving round a dial plate, shows how much thread has been delivered by the drum. Each bobbin is next inserted into a *bobbin-carriage*, seen in front and in side section, fig. 205. The bobbin is inserted in the space, G, the narrow edge, *e e*, fitting the grooved borders of the bobbin, while the spring, *f*, prevents the bobbin from falling out. The thread is conducted through the eye, *g*, at the top of the carriage, and on pulling this thread, the bobbin turns round.

These details being understood, we may describe the action of the bobbin-net machine by means of fig. 209, which shows the working parts. We have referred to this machine as being complicated. Now, complication in a machine may arise from the multiplication of similar parts, or from a large assemblage of different parts. Any one looking into the case of a church organ would pronounce that instrument to be very complicated, but it really is not so; the apparent complication arises from the frequent repetition of the same parts. A steam-engine, or a steam printing-press, on the contrary, is complicated, because in either case there are many different parts and many different motions to be followed out and understood. The bobbin-net machine involves both these conditions. The parts are numerous, and some of those parts are repeated many hundred times. In order, therefore, that the reader may follow out our description, we insert the principal illustrative diagram in the body of the text; and it will be understood that the motions described for two bobbin-carriages, two warp-threads, &c., apply equally to ten or fifteen hundred repetitions of the same parts in the same machine.

The warp-thread is wound upon the roller, C, while at the top of the frame a similar roller, D, receives the finished work. Between these two rollers the warp-threads are extended in vertical lines. F F are guide-bars, extending the whole length of the machine, with slits in their edges, through which the warp-threads are conducted in two rows, one on each side, to the eyes, *b b*, of



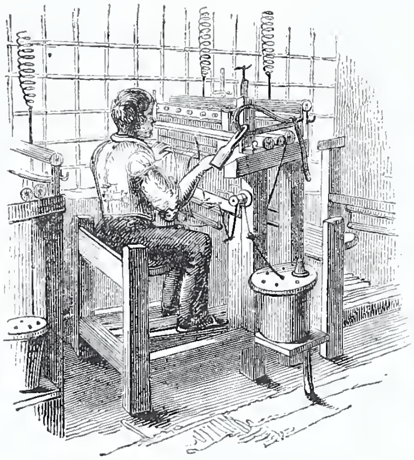
209. WORKING PARTS OF BOBBIN-NET MACHINE.

needles, one of which is shown separately in fig. 206. Each guide-bar, which contains a range of these needles equal to one-half the number of threads in the warp, is arranged so as to shift slightly to the right or to the left, to allow the bobbin-thread to pass to the right or to the left of the warp-threads as often as it is necessary to form the twist. The number of bobbins with their carriages is equal to the number of the weft-threads ; and as these have to pass through the narrow intervals of the warp-threads, they are arranged in a double line in two rows, G G, on each side of the warp-threads. The bobbins are supported between the teeth of a kind of comb, *k k* (a portion of which is shown separately in fig. 208), for which purpose the bobbin carriages have a groove, *h h*, fig. 205, corresponding to the interval between every two teeth of the comb. There is one comb on each side of the warp, and the free ends of the teeth in the opposite combs stand so near to each other as to leave room merely for the proper motions of the warp-threads between them. Hence the bobbin carriages, in passing across through the intervals of the warp, reach the back bolts before they have entirely quitted the front ones. The carriages are driven alternately from one comb to the other, by two bars, *l l;* and when one of the lines of carriages is pushed nearly across the intervals of the warp, the foremost of their projecting catches, *i i*, is engaged by a plate, *n*, attached to a shaft, I, which pushes it quite through. The beam which carries the combs can be shifted a little to the right or to the left, so as to change the relative position of the opposite combs by one interval or tooth, and thus to transfer the carriages to the next adjoining teeth. By this contrivance the bobbin carriages make a succession of side-steps, to the right in one comb, and to the left in the other, in the course of which counter-march they cross each other and their threads twist round the vertical warp-threads, and thus form the meshes of the net. A *point-bar*, L, containing a row of pointed needles, one of which is shown separately, fig. 207, then falls with its points between the warp and weft threads, and carries up their interlacements, so as to form a new line of holes or meshes. The whole working of the machine thus becomes a constant repetition of twisting, crossing, and taking up the meshes on the point-bar.

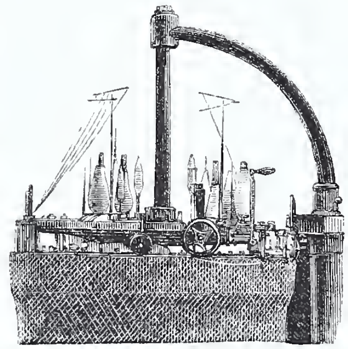
The beauty of bobbin-net lace depends on the quality of the threads, and the equal size and hexagonal shape of the meshes. The closer the warp-threads are together, the smaller are the meshes and the finer is the lace. The number of warp-threads in a width of one yard may vary from 700 to 1200; the fineness of the lace, or the *gauge*, or *points* as it is called, depends on the number of slits or openings in the combs, and consequently on the number of bobbins in an inch of the double tier. A length of work counted vertically, containing 240 holes or meshes, is called a *rack*. Well-made lace has the meshes slightly elongated in the direction of the selvage. A piece of bobbin-net may be twenty, thirty, or more yards in length, and of variable breadth. The narrow quillings used for cap-borders are worked in the same frame: many breadths at once are united by a set of threads, which are afterwards drawn out.

English machine-made net is chiefly confined to *point-net*, *warp-net*, and *bobbin-net*, so called from the peculiar construction of the machines by which they are produced.

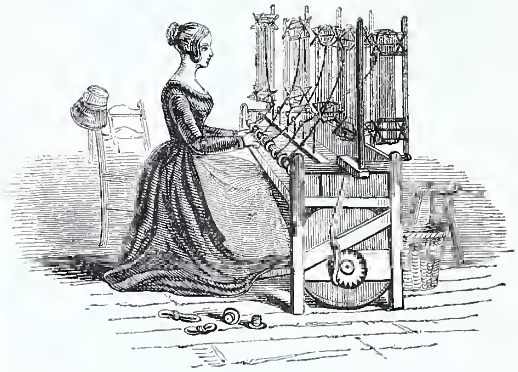
After the lace has been removed from the machine, it is *gassed* by being passed over a row of gas flames, supplied by the apparatus represented at fig. 204. The lace is then examined, defective meshes are mended by women, called *lace-menders*, who have a method of perfectly restoring the damaged meshes. It is then dressed, rolled, ticketed, and made up, processes similar to those already described for muslin.



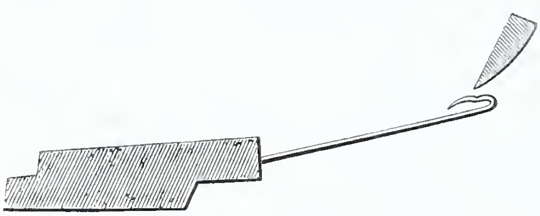
210. HOSIER AT WORK.



211. CIRCULAR LOOM.

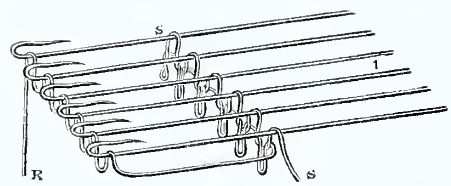


212. WINDING.

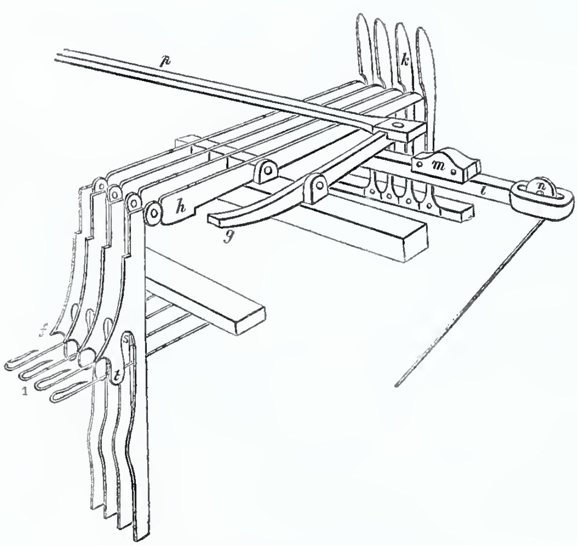


213. NEEDLE OF THE ACTUAL SIZE.

214. CAVITY.

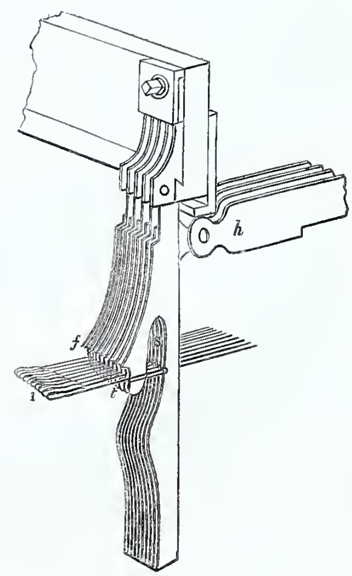


215. NEEDLES AND LOOPS.



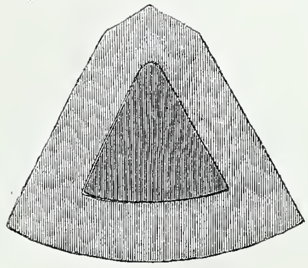
216. JACKS, SINKERS, AND SLUR.

218. BARREL FOR BOBBINS.



217. SINKERS.

219. FILAMENT OF WOOL (*Magnified*).



227. PULL-OVER.

222. HARE'S FUR.

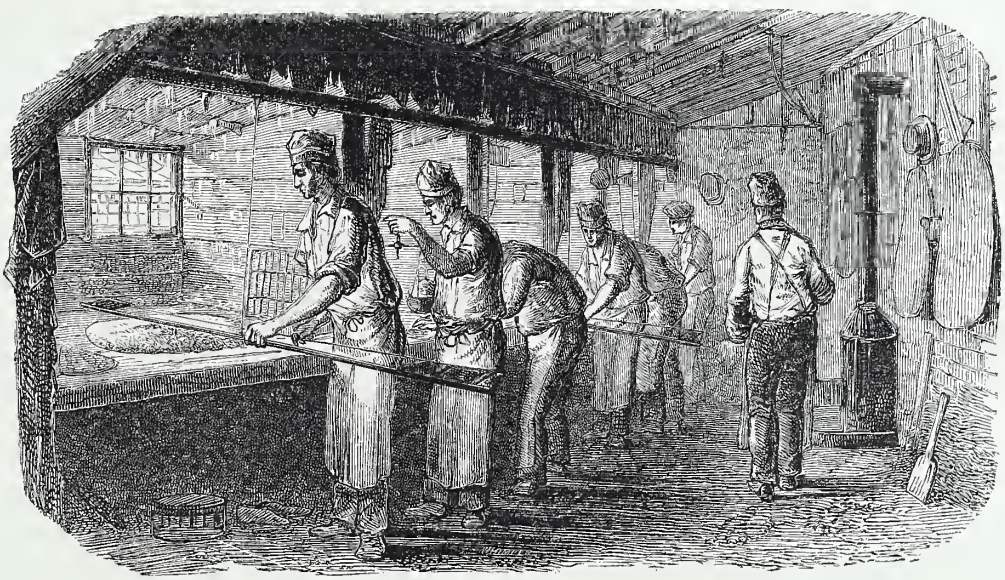
220. STRUCTURE OF NEUTRIA.

223. STRUCTURE OF RABBIT'S FUR.

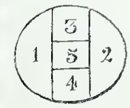
221. STRUCTURE OF MUSQUASH.

228.

229.

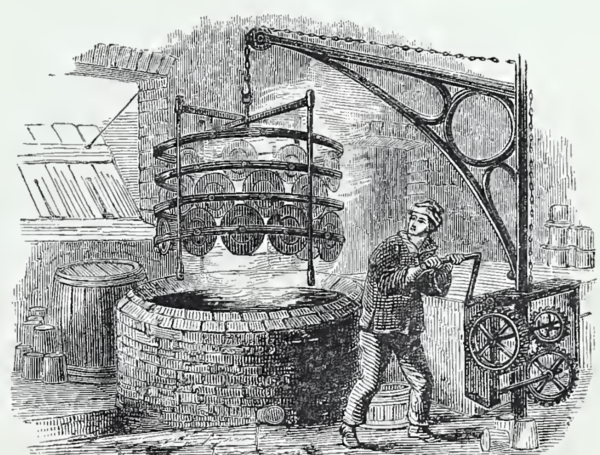


224. BOWING BEAVER FUR.



230.

225. HAT BATTERY.



226. HAT-DYEING.

XII.—HOSIERY.

The *Stocking-frame* is an ingenious contrivance for knitting by machinery instead of by hand. In *knitting*, a single thread is entwined so as to produce a fabric consisting of a succession of loops. In *netting*, a single thread is formed into meshes, produced by tying the thread or cord into hard knots at those points where it crosses upon itself. If the thread of a stocking be broken, a hole is produced, which continually enlarges by the unlooping of the thread; but one of the meshes of a net may be broken without injury to the rest.

The stocking-frame is a rare example of a capital invention, made in an age by no means distinguished for inventive skill in mechanics. The age which produced Shakspeare and Spenser, Bacon and Raleigh, distinguished as it was by the highest order of genius, did not understand the advantages of machinery in stimulating production; but, on the contrary, regarded with suspicion whatever tended to abridge the labour of the hand. The answer of Queen Elizabeth to Lord Hunsdon, on being applied to for a patent for the stocking-frame, is characteristic of a policy which may be traced even to our own times. "My lord," said her majesty, "I have too much love to my poor people, who obtain their bread by the employment of knitting, to forward an invention which will tend to their ruin, by depriving them of employment." It is hardly necessary to remark, that, at the time when the queen made this generous resolve, the upper classes only could afford to wear stockings, on account of their high price; but the introduction of the stocking-frame increased production to such an extent, that stockings came to be regarded as a necessary article of dress by all classes of the community, thereby increasing the number of persons engaged in producing them many hundred fold, as compared with those engaged in knitting.

In the Stocking-Weavers' Hall in Red Cross Street, London, is a picture representing a man pointing to a stocking-frame, and addressing a woman who is knitting. There is the following inscription to this picture: "In the year 1589, the ingenious William Lee, Master of Arts, of St. John's College, Cambridge, devised this profitable art for stockings (but being despised, went to France), yet of iron to himself, but to us and others of gold; in memory of whom this is here painted."

The idea of devising the stocking-frame is said to have occurred to Lee, while courting the lady whom he subsequently married. The damsel being constantly engaged in knitting, the young man, from watching the dexterous movements of her hand, conceived the idea of making artificial fingers for knitting many loops at once. From this time the ardour of invention took full possession of his mind. Success as an inventor did not, as it now generally does, involve success as a manufacturer. After many fruitless attempts to introduce his machine in this country, he sought refuge in France; and, under the auspices of the prime minister of Henry IV., established his frames at Rouen. Just as his plans were apparently about to succeed, the king was murdered, Lee was proscribed as a Protestant, and being forced to conceal himself in Paris, died there in poverty and distress. The workmen whom Lee had taken to Rouen, returned to London; and through their means a company was formed, which afterwards became a corporate body.

It is not necessary to trace the steps by which the ingenious machine, which was "of iron" to the inventor, "but to us and others of gold," came into general use; but we will at once proceed to a description of the machine itself.

Knitting, which is imitated by the stocking-frame, is performed by a couple of straight wires called *knitting-needles*, and the operation consists in forming a series of loops upon one needle and inserting them within another series formed upon the other needle. This operation is brought about by four movements. 1. Pushing the right-hand needle through the first loop of the left-hand needle; 2. Turning the thread once round the right-hand needle, in order to form a new loop; 3. Drawing the new loop through one of the former series; and 4. Pushing the old loop off the left-hand needle. When one row of loops is completed, the needles change hands, and a new course is commenced.

In knitting by the stocking-frame, the number of needles may vary from fifteen to forty in an inch, according to the fineness of the work. They are made of iron wire (fig. 213), with a hook or barb at the end, and a cavity in the stem, beneath the bar (fig. 214), to receive the point when pressure is applied on the hook, by the edge of a *presser-bar*, a section of which is shown in fig. 213, by which means the barb becomes a closed eye. Now suppose a number of these needles fitted into the frame side by side, as in fig. 215, the operation of the machine is to form of the single thread, R, a series of loops, S S, and then to draw them through a series of other loops previously formed. The loops are formed by levers called *jack-sinkers* and *lead-sinkers*. The jacks, *h*, fig. 216, are horizontal, and move upon a common centre, each having a joint from which hangs a sinker of thin polished iron plate. A jack and a sinker is assigned to every alternate needle in the frame, the sinkers hanging between them as in fig. 217. The other ends of the jacks are secured by small iron springs, *k*. The lead-sinkers resemble the jack-sinkers, but are differently attached; for while the jack-sinkers admit of being raised or lowered separately, the lead-sinkers are all fixed to what is called a sinker-bar, and must be raised or lowered altogether. The lead-sinkers are placed alternately between the jack-sinkers, so that between every two sinkers there is a needle. When the jack-sinkers are raised, so as to bring their *nips*, *f*, above the level of the needle, the thread is loosely thrown under them, so that on lowering the jacks a series of loops are formed as in fig. 215; but if the jacks were all lowered at once, there would be danger of destroying the thread. This is prevented by a piece of metal, *m*, fig. 216, called the *slur*, which moves upon a bar, *l*, called the *slur-bar*, extending beneath all the jacks. By making the slur travel under the jacks, only one jack-sinker is lowered at a time, and the loops are formed between the needles, not all at once, but in succession. But the loops thus formed are of double the depth required; and to bring them to the proper size, and to distribute them between every two needles, the weaver depresses the lead-sinkers all at once, and their nips, *f*, carry down the thread between the remaining needles. While this is being done, the jack-sinkers are made to rise up as much as the lead-sinkers descend, so that the loops thus become of the same size. This row of loops is next driven back upon the needles to S S, fig. 215, so as to come below the arch or opening of the sinkers S S, figs. 216, 217. Here the loops are entirely removed from the action of the sinkers, and the workman proceeds to form a new row in front of the former. This second row of loops is then brought forward so as to be under the barbs or hooks of the needles. The presser-bar is next made to close the barbs with the thread within them: the first-formed loops are now brought forward from under the arch, upon the closed needles, and are made to pass over the ends of the needles and over the newly-formed loops within them, so that the loops of what was the upper or last course of the finished work become secured, and the loops under the barbs now become the upper course, and are preserved from unravelling by the needles, one of which passes through each loop, and these loops will not be drawn off from the needles until there is another row of loops prepared and ready to be drawn through them.

It may assist the description if we now recapitulate the various movements of the frame. Supposing the weaver to have put back the work on the needles, preparatory to another course, the first movement is the *gathering of the thread*. The thread is lightly extended across the needles, *f*, of the sinkers; and, by pressing the slur treadle, the jack-sinkers are depressed one by one so as to form double loops: this is called *drawing the jacks:* the second movement is called *sinking*. The lead-sinkers are depressed and the jack-sinkers raised, whereby the thread is carried down into a loop between every two needles. The third movement is to bring the thread under the barbs of the needles. The fourth movement is to bring the work forward from the stems of the needles towards the barbs. The fifth is to close the barbs, by the pressure of the presser-bar, and to draw the loops last made through the finished loops of the work. The finished loops are drawn over the barbs, and quite off from the needles. This draws the finished loops over the loops last made, which remain in the barbs. For cotton hose the thread is wound upon bobbins, as shown in fig. 212, where the hanks of thread are spread over reels, and the thread passes through metal eyes to the bobbins. For silk hose the bobbins are placed in a barrel, fig. 218, containing a little water, the evaporation of which keeps the thread sufficiently damp for working. The thread is drawn out through a hole in the cover of the barrel, as shown in fig. 218.

A circular loom, fig. 211, has of late years been introduced; and the amount of work it is able to perform is prodigious. A machine with four feeders and 1,200 needles on the circumference, will make 80 revolutions, or 96,000 loops, per minute.

XIII.—HATS.

The production of a beaver hat depends on the curious property possessed by certain animal fibres of matting together into a kind of cloth called *felt*, and the process by which this is done is called *felting*.

A fibre of lambs' wool examined under the microscope presents the appearance represented in fig. 219. The jagged edges of cleaned wool, when subjected to gentle friction assisted by moisture, lock into each other, or felt together, a property which was probably known at a remote period; although there is some doubt whether the *lana eoacta* used by the ancients as cloaks for the soldiers, for corslets and horse furniture, was true felt. Wool is not the only material capable of being felted, as will be seen by the structure of various descriptions of fur represented in figs. 220 to 223.

There are three descriptions of hat prepared by felting: first, the *beaver hat*, properly so called, consisting of a body or foundation of rabbits' fur, and a beaver nap. Second, the *plate-hat*, in which the body is of lambs' wool, *plated* or napped with musquash, neutria, or some inferior fur. Third, the *felt hat*, which is a wool body without a nap.

In making a beaver hat, a *hat body*, or foundation of wool, is taken. This is in the form of a conical cap, represented by the darker figure in fig. 227. The workman weighs out one ounce of beaver down, a quarter of an ounce of musquash, and the same quantity of cotton wool. These materials being placed on a table, fig. 224, are spread out and mixed by the operation of *bowing*, as in the case of cotton (fig. 7). The bow is held in the left hand, and is attached by a cord to a beam above, so that it may be held at a proper distance; and then, with the knob of a wooden pin, the man sets the string of the bow vibrating among the fibres, the effect of which is to cause them to fly into the air, and in falling to occupy a much larger space than they did before. To prevent them from being too much dispersed, a wicker frame called the *basket*, shaped like a fire-guard, is set up on end, with its concavity towards the fur. The bowing is repeated two or three times, until the fur is spread out into a large oval *sheet of napping*, as it is now called. It is then pressed down with the hands, and afterwards with a skin of leather, called the *hardening skin*. It has now the appearance of thin flannel; and is of the form represented at No. 1, fig. 228. It is then folded into the form No. 2, fig. 229, and then into that of No. 3. The woollen hat body, fig. 227, is then placed on No. 3, and the portions of napping not covered with the body are torn away. These are bowed again into another sheet of napping, which is afterwards added to the crown of the hat, which, having to be distended out of a conical body, must necessarily be stretched, and thus require an additional quantity of fur.

The operations are next transferred to the hat-battery, fig. 225, which consists of a boiler surrounded by sloping mahogany sides, and containing water acidulated with a little sulphuric acid, together with beer-grounds or oatmeal. The conical hat-body is held in the hot liquor, and when sufficiently soft is placed on the plank, and is covered with a portion of the beaver napping. It is then turned over, and the remaining portion of the napping is made to cover the other side. By means of a brush, a roller, and a piece of wood covering the palm, called a *glove*, the nap body is worked about for a considerable time. The fur soon begins to strike into the woollen felt of the hat-body; but the cotton wool, which is incapable of felting, comes away, and shows that the fur has properly combined with the body. Shape is given to the nap-body by drawing it over a wooden cylindrical block; and by dint of much working and pressing, the cone becomes nearly cylindrical in shape. And lastly, the brim is worked to the proper form.

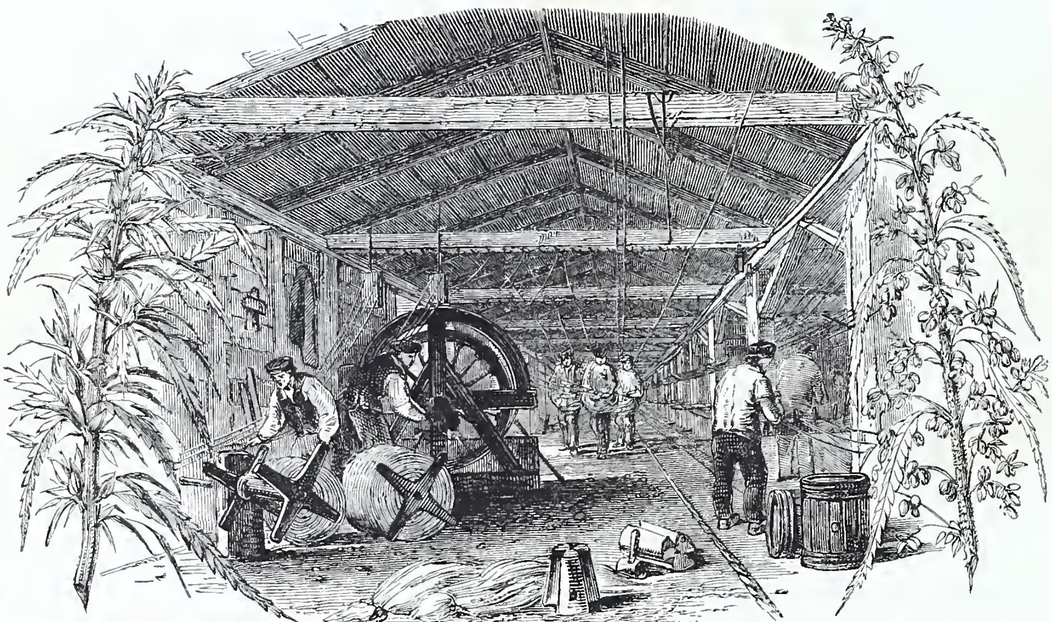
In some cases the beaver is formed into what is called a *pull-over*, for which purpose the sheet of napping is formed into the shape of a hat cone, and is folded up with a triangular piece of brown paper, fig. 227, to prevent the opposite surfaces from coming in contact. The hat cone, fig. 227, is then placed on it, and they are worked together by a process called *basoning*, a metal plate or bason being formerly used instead of the brown paper.

The beaver hats are next combed, and the tips of the hairs cut off with a pair of shears; after which they are mounted on blocks, suspended in an iron frame, and lowered into the dye copper, fig. 226; after which they are smoothed and finished by means of warm and damp hair brushes, hot irons, and a plush cushion, called a *velour*. *Trimming*, *binding*, and *lining*, and lastly *blocking*, or giving a modish shape to the hat, are the finishing operations.

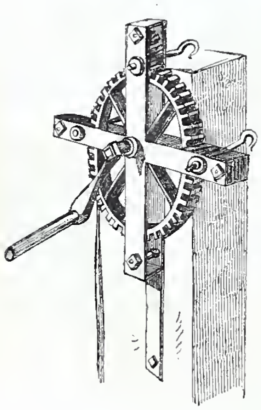
The silk hat, which has now for the most part taken the place of the beaver, is produced in a much simpler manner. The body is formed by cementing layers of calico upon a hat-block, fig. 230, consisting of five pieces; and when the brim is attached, the whole is covered with cement, and then covered with a silk plush, manufactured for the purpose, and made to adhere by the application of moisture and heat.

231. RETTING, BREAKING, HECKLING, AND DRYING HEMP.

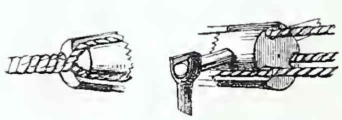
232. HECKLING MANILLA HEMP.



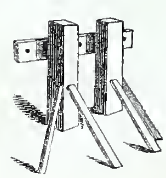
233. ROPE-WALK—SPINNING YARNS.



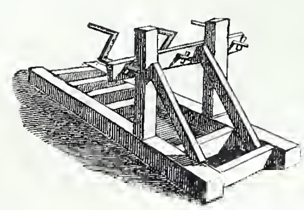
234. WHEEL FOR TWISTING STRANDS.



235. TOPS FOR LAYING STRANDS.

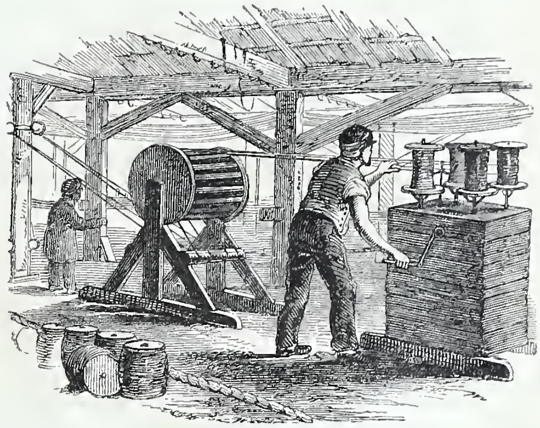


236. TACKLE BOARD.

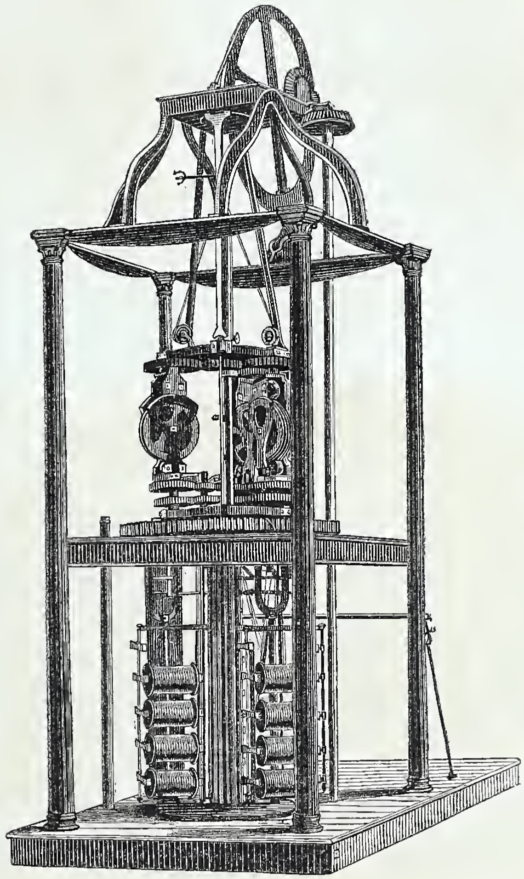


237. SLEDGE .

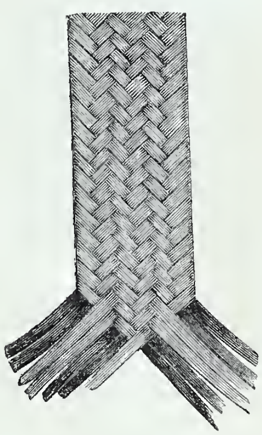
238. SPINNING YARNS.



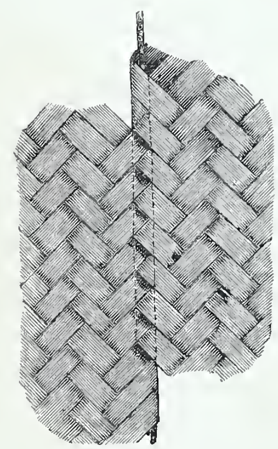
239. REELING YARNS.



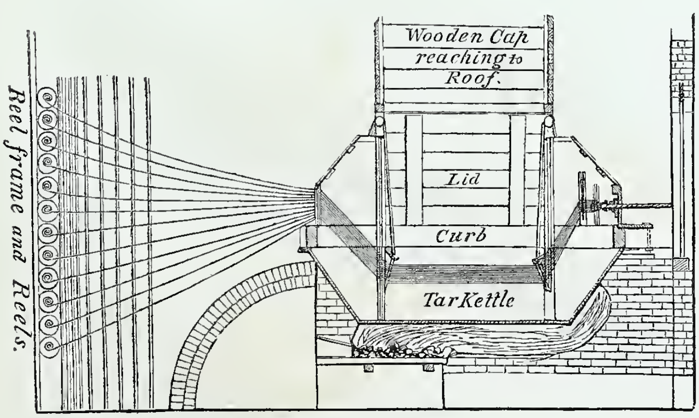
240. ROPE-MAKING MACHINE.



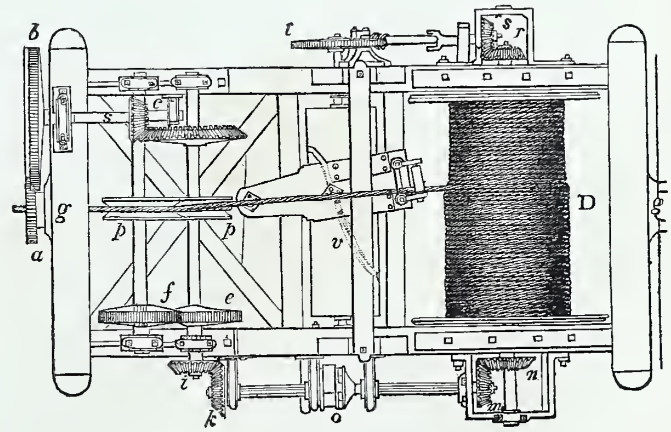
243. ITALIAN STRAW-PLAIT.



244. METHOD OF JOINING.



241. TARRING YARNS.



242. REGISTER MACHINE.

XIV.—ROPES AND CORDAGE.

If all the cordage, great and small, of a first-rate ship of war were tied together, end to end, it would measure 43 miles; it would weigh $78\frac{1}{2}$ tons, and would cost 3,276*l.* sterling. Smaller vessels, whether of the navy or of the merchant service, cost similar sums for their cordage, in proportion to their size. In a free maritime country like the British Isles, whose ships visit every habitable coast, and ascend every navigable river of the earth, the importance of the rope manufacture can scarcely be over-estimated. A portion of that busy shipping is employed in bringing to these shores the raw material for those innumerable lines, which give such a trim and beautiful appearance to a well-rigged vessel, to say nothing of the numerous other uses to which ropes, cord, string, &c., are daily and hourly applied. In the year 1856, there were imported into the United Kingdom considerably more than a million and a half *cwts.* of hemp; and, considering the importance of the manufacture, we see the wisdom of our Legislature in making it free of duty.

Hemp is the principal but not the only material for rope-making. The husk of the cocoa-nut, the fibres of the wild banana, various kinds of tough grass, horse-hair, wool, thongs of leather, metal wires, &c., are all used as materials for ropes. The native rushes or *junci* of this island were employed at an early period for making ropes; and the practice is perpetuated in the term *junk*, which is applied to worn-out ropes.

Hemp (*Cannabis sativa*) is stronger and coarser in the fibre than flax; but its uses, culture, and management are nearly the same. It is an annual plant, usually about five or six feet in height; and from the circumstance of the flowers and the fruit growing on separate plants, hemp is distinguished as *male* and *female*. The supporters to fig. 233 represent the two varieties. The *retting*, *breaking*, *heckling*, and *drying*, fig. 231, resemble those operations already described under flax, so that we may proceed at once to the business of the manufacture.

The word *rope* properly belongs to cordage above an inch in circumference, the smaller kind being named *twine*, *cord*, and *line*. In making a rope, the hemp is first spun into *yarn*. A number of yarns are twisted into a *strand*, three strands twisted together form a *rope*, and the twisting together of three ropes forms a *cable*.

The object of twisting the fibres is to produce sufficient compression to prevent them from sliding over each other when a strain is applied. Twisting does not increase the strength of the fibres, but, on the contrary, greatly diminishes it. A rope formed by arranging the fibres side by side and fastening them at the ends, is much stronger than the same number of fibres twisted into a compact cord. In the one case each fibre bears its own share of the strain, and the strength of the bundle is that of the sum of the strengths of the separate fibres. In twisting the fibres, those on the outside will evidently be strained more by the twist than the inner ones, and, consequently, will be less efficient in supporting a weight, or resisting a pull. In an experiment tried for the purpose, the untwisted fibres supported 98lbs., and the twisted only 65lbs., showing a loss of strength from twisting equal to 33lbs. But as twist is necessary to get length, it is adopted, subject to the maxim, that all twisting, beyond what is necessary to prevent the fibres from slipping on each other, is to be avoided.

The first operation in the manufacture of a rope is *heckling*, for the purpose of separating and straightening the fibres, so that they may run freely in spinning. A weighed quantity of hemp, sufficient to form one yarn 160 fathoms long, is thus combed out at each operation. The *heckle* (fig. 232) consists of a number of steel prongs, set up in a board with the points upwards, as already described for flax; but in heckling hemp, a little whale oil is applied to the points from time to time to assist the operation. Each heckled portion is tied up into a bundle, called a *tow of hemp*, one of which is represented in the right-hand corner of fig. 232.

The hemp thus prepared is next spun or twisted into yarn; the spinning is usually carried on in a long covered walk, called the *spinning-walk* (fig. 233), one end of which is called the *head*, or *fore-end*, and the other the *foot*, or *back-end*. At one end is a *spinning-machine*, consisting of a wheel, over which passes a band, which gives motion to a number of *rollers* or *whirls*, furnished with little hooks, which are set rapidly spinning by turning the wheel. As many spinners may work together as there are whirls in the frame: each spinner then takes a tow of hemp, and wrapping it round his body, draws out from the face of the bundle as many fibres as he thinks necessary for the size of the yarn, and attaches the *bight* or *double* of the fibres to one of the whirl-hooks, while an assistant turns the wheel, and throws *twist* or *turn* into the fibres. The spinner (figs. 233 and 238) has a piece of thick woollen cloth in his right hand, the end of which hangs over the fore-finger. With this he grasps the fibres as they are drawn out, pressing them firmly between his two middle fingers. He walks backwards towards the foot of the walk, and with his left hand regulates the supply of the fibres, so as to make the yarn of equal size, the thickness of the yarn depending on the quantity of hemp which the spinner allows to pass through his hands in a given time, and also on the rapidity with which the hook is made to rotate. As the yarn increases in length, the spinner throws it over hooks fixed to the under side of the rafters of the roof. Arrived at the lower end of the walk, a man at the wheel takes the yarn off the hook and fastens it to a reel, which is then turned round, while the spinner walks slowly in, keeping the yarn stretched all the way.

The next process is *tarring*, for which purpose 300 or 400 yarns are placed side by side, and passed through hot tar. They are dragged out through a hole called a *grip*, or *sliding-nipper*, which presses the tar into the yarn, and gets rid of the superfluous portion. Tarred cordage has not the strength of untarred; but it resists the wet better.

The next operation is *twisting* or *laying* the yarn, either tarred or untarred, into strands. The *laying-walk* may be under the same roof as the spinning-walk (fig. 233). At the head of the walk is a *tackle-board* (fig. 236), which is a plank supported by strong upright posts, and pierced with three holes, corresponding to the number of strands in a rope: *winches* or *fore-lock hooks* work through these holes. The smaller strands are twisted by the wheel (fig. 234). The yarns, preparatory to laying, are attached to posts at the side of the walk, as shown in fig. 233, or they are wound upon reels, as in fig. 239. As the yarns are twisted together into a strand, they are attached to a movable *sledge* (fig. 237), the upper part of which has a *breast-board*, corresponding to the tackle-board. The sledge is kept steady by being loaded with weights. The proper number of yarns for each strand is attached to the hooks of the tackle-board, and of the sledge. The latter is then pulled backwards until the yarns are stretched tight, when the hooks, both of the tackle-board and of the sledge, are heaved round in a direction contrary to the twist of the yarn, by which means the three bundles of yarn are formed into a strand. The shortening of the yarns, by the twisting, draws the sledge forward; and when the strand is *full hard*, or has enough *hard* in it, as the twisting is called, the process is complete.

The next operation is *laying*, or twisting three strands together to form a rope; for which purpose the three strands are attached to the middle hook of the tackle board, and all three are inserted

into the grooves of a piece of wood called a *top*, fig. 235. On twisting the three strands together, the top is forced forward, and the rope is formed. In the laying of three strands together, the rope is said to be *hawser-laid*. In this process, which is called the *first lay*, each strand consists of as many yarns as are necessary to give the required thickness to the rope. The *second lay*, or *shroud hawser-laid rope*, consists of four strands, with a straight loose strand or *core-piece* running through the centre, to render the rope solid. In the *third lay*, or *cable-laid rope*, three hawser-laid ropes, each formed of three large strands, are twisted or laid together, so as to form one gigantic rope or cable. This, however, has of late years been superseded by the chain cable.

Machinery has been applied with considerable success to the manufacture of ropes. We do not pretend, of course, in these short essays, to present more than a very few rough outlines of the important subjects of which they treat; and our outline, such as it is, often refers to one machine, or set of machines, while we pass over others which produce similar results by different means, but quite as efficiently. In noticing Captain Huddart's *Register-machine*, we wish to refer to it as one out of several inventions for accomplishing the same object.

The yarns, having been spun by machinery similar in principle to that already described for cotton and flax, are wound upon reels, and mounted in a *frame* (fig. 241), whence they proceed through a tar-kettle, and passing through certain plates, which get rid of the superfluous tar, are passed through a tube, and thence to the registering machine, fig. 242, which twists them into strands. This consists of a square frame of wood, supported horizontally upon two small gudgeons, *g g*, upon which the frame, with the machinery contained within it, revolves. The strand enters this frame through one of the gudgeons, and passes under and over two pulleys, *p p*, on its way to the winding-drum. Motion is given to the pulleys by connecting the pinion *a* with the toothed wheel *b*, the spindle of which, *s*, carries a bevel-pinion, *c*, which works another bevelled wheel attached to the spindle that carries one of the pulleys, while the toothed wheel, *e*, in gear with *f*, gives motion to the other pulley. Now it will be evident that, as the whole frame revolves, the yarns from fig. 241 will be twisted into a strand, and that the motion of the pulleys *p p* will drag it forward through the register tube. The same motion which produces these operations winds the finished strand upon the drum *D*. The motion is given to the drum by connecting the small mitre pinion *i* with a similar pinion, *K*, and this is connected by means of the spindle with the pinions *m* and *n*, the latter of which is fixed to the axis of the winding drum. As the frame revolves, the two pulleys and the winding drum thus have their own distinct revolutions. As the coiling advances, the increased size of the drum would give an increased strain to the strand were it not provided for by dividing the spindle *o* into two equal parts, uniting them by means of a clutch at *o*, which slips upon itself whenever the drum tends to over-wind the pulleys, and thus the drum remains stationary for a moment, while the strand slackens a little. In order to wind the strand in regular coils upon the drum, the opposite end of the axis has a mitre pinion, *r*, in gear with a similar one, *s*, attached to a short spindle, which is furnished with a universal joint acting upon the forked end of an oblique spindle which bears an endless screw, working into a toothed wheel, *t*; this wheel is fixed upon the end of a spindle placed across the frame, carrying a wooden roller, *v*, which thus acquires a slow rotatory motion. Upon this roller is a long endless groove, shown partly by the dotted lines; in this groove there fits a stud, which projects from the under face of a guide frame. As the drum revolves, the roller slowly moves, and shifts the guide frame alternately from side to side. The strands thus formed are now ready to be laid into ropes, an operation which is effected by a *rope-laying machine*.

The machine represented in fig. 240 lays the yarn into strands, and the strands into ropes, at one operation.

The cordage made for the use of the British navy is distinguished by a coloured worsted thread in the centre of each strand, and every combination of strands or rope is also distinguished by a simple yarn of peculiar make laid in its centre.

XV.—STRAW PLAIT.

We have now brought to a conclusion our notices of spinning and weaving. We may, however, refer to an important branch of industry which belongs to that kind of weaving called *plaiting*. The manufacture of straw hats attained great perfection in Italy more than two centuries ago. But it was not until the long-continued war with Napoleon arrested the import trade, that the home manufacture rose into importance. The Tuscan straw is from a variety of bearded wheat (*Triticum turgidum*), which is grown in Tuscany for the sake of the straw: this is pulled while the ear is in a soft milky state, the corn having been sown close, so as to produce it in a thin, short, and dwindled condition. It is dried by exposure to the sun, then laid up in bundles and stacked for about a month, after which it is bleached by exposure to moisture, light, and air. The bleaching is completed by means of the fumes of sulphur.

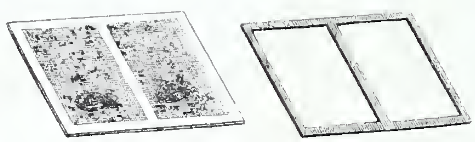
In the Italian method of plaiting, the straws having been sorted as to colour and thickness, thirteen are usually selected, tied together at one end, and then divided into two portions, six straws being turned to the left and seven to the right, so that the two portions of straw may form a right angle. The plaiting then proceeds in the manner represented in fig. 243. The plait is formed in pieces of great length, which are adjusted in spiral coils, with their adjacent edges knitted together, so as to form the large circular *flats* which were formerly extensively exported from the north of Italy. Fig. 244 shows the method of knitting the edges together; the dotted lines indicate the edges of each piece of plait, and show how far the angular folds or *eyes* of one piece are inserted into those of the adjoining piece. The thread by which the two rows are held together is entirely concealed in the plait.

The British straw-plait district is in Bedfordshire, Hertfordshire, and Buckinghamshire; the manufacture is also carried on in Essex, Suffolk, and elsewhere. There are many varieties of plait in general use, such as *Whole Dunstable*, consisting of seven entire straws; *Patent Dunstable*, or *Double seven*, formed of fourteen split straws; *Devonshire*, formed of seven split straws; *Luton plait*, formed of double seven, but coarser than patent Dunstable: *Bedford Leghorn*, formed of twenty-two, or double-eleven straws; *Italian*, formed of eleven split straws. There are several varieties in *Fancy Straw Plait*, such as the *Back-bone*, of eleven straws; the *Lustre*, of seventeen straws: the *Wave*, of twenty-two straws; and the *Diamond*, of twenty-three straws; nor must we forget to mention the *Rustic* of four coarse split straws, and the *Pearl*, of four small entire straws.

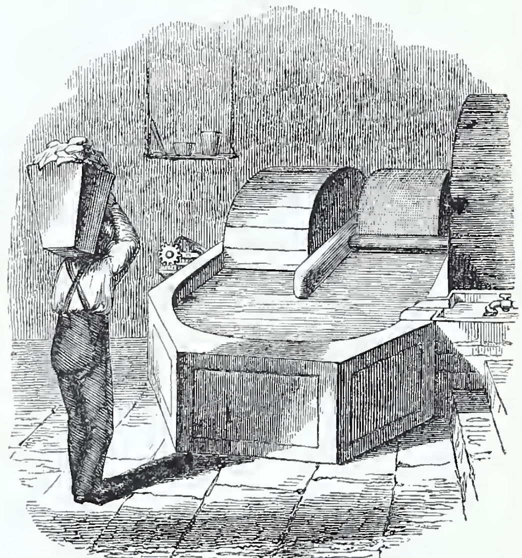
About 70,000 persons are engaged in the production of straw-plait, which still maintains its ground, notwithstanding the use of silk and other materials for bonnets. This arises from the circumstance that the whole of the female population in Great Britain wear bonnets, which is, probably, not the case in any other part of the world, with the exception of North America.

245. PAPER MILL.

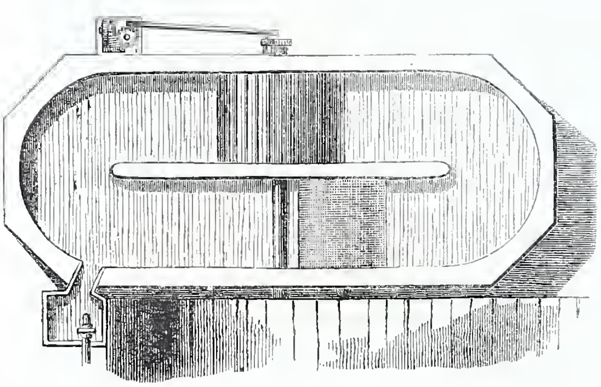
246. RAG-CUTTERS AT WORK.



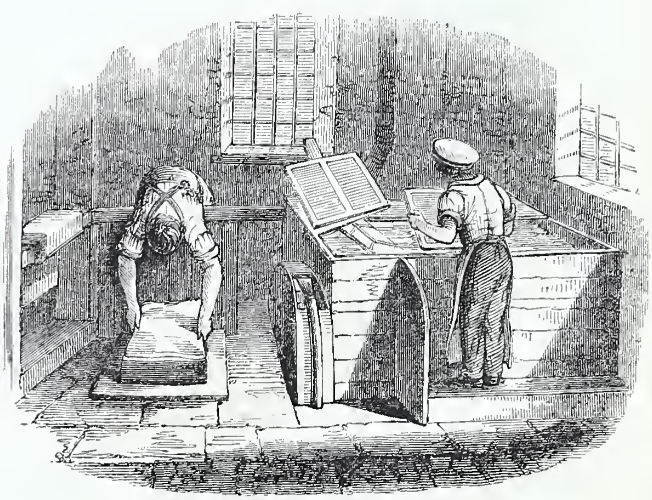
248. PAPER MOULD AND DECKLE.



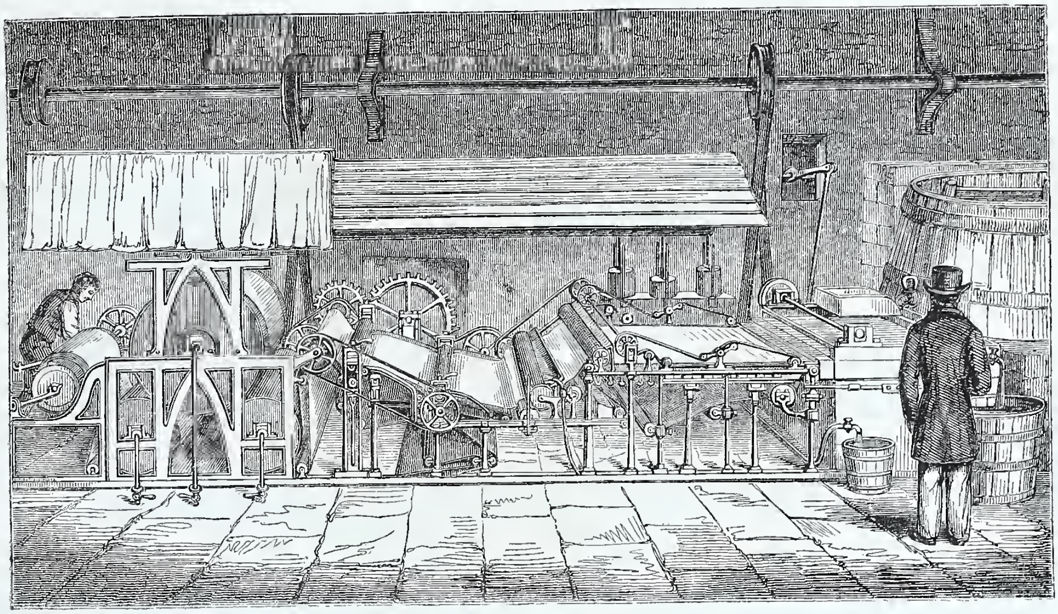
247. WASHING ENGINE.



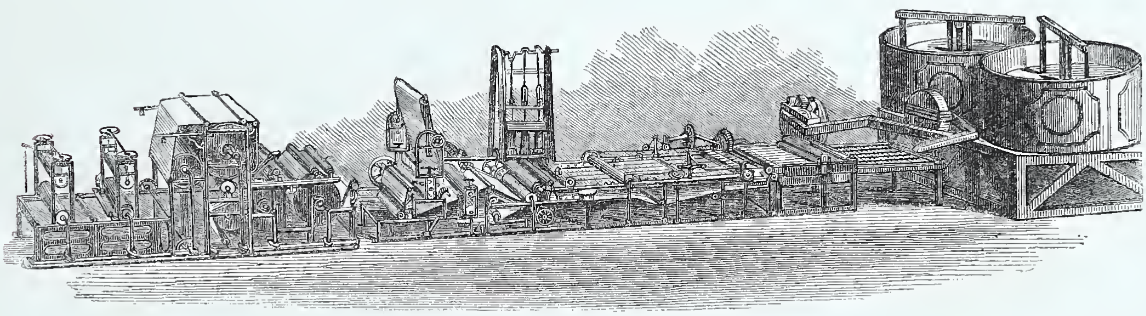
249. BEATING ENGINE.



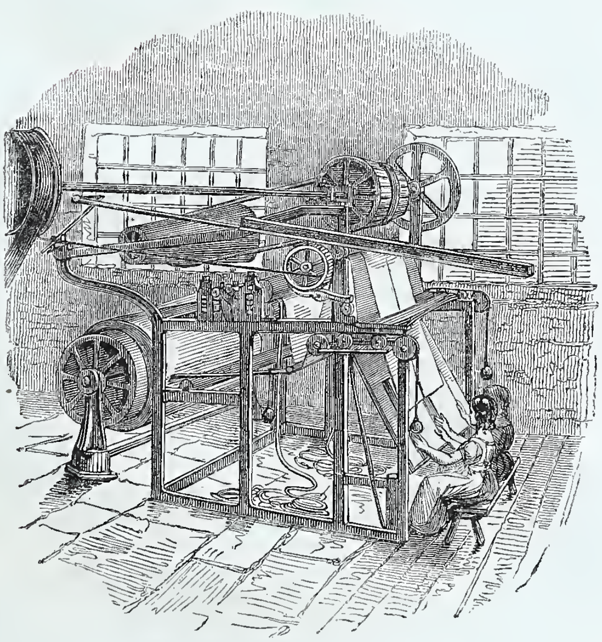
250. MAKING PAPER BY HAND.



251. PAPER-MAKING MACHINE.



252. ANOTHER FORM OF PAPER-MAKING MACHINE.



253. PAPER-CUTTING MACHINE.

254. ENVELOPE-FOLDING MACHINE.

XVI.—PAPER.

The manufactories which have hitherto engaged our attention are, for the convenience of markets for the raw material, and for the sale and transport of the finished product, situated in densely crowded cities and towns, where the engineer and other persons subsidiary to the great staple trade of the place reside, and all more or less seem to be urging on one or other branch of the great manufacture. A stranger, walking through one of these vast manufacturing centres, has before his eye at every turn one of those huge factories which have been erected evidently with a view to utility rather than beauty of proportion (although in some cases both have been happily combined). The tall chimneys pour out their volumes of smoke, often in despite of the smoke-consuming apparatus with which the furnaces are provided. Everywhere do we hear the heavy respirations of the steam-engine, the pulsations of endless machinery, the rattle of spindles, and the whirl of wheels: we are conscious of incessant activity, and feel almost ashamed of strolling about as an idle spectator in the midst of a toiling population. We leave the town by roads which are ground to dust by the endless traffic, and find the neighbourhood equally busy. Instead of farms and rural scenes, we have workshops, forges, tall chimneys, canals, and railroads; and should there be a river, which once sparkled in the bright sunshine, it has long since been yoked to labour, and is not allowed to descend through a foot of its course without having work to do. Its banks are crowded with bleach-works, dye-works, cotton-mills, water-wheels, and machinery; and lest it should fail in its laborious efforts, catch-pools are erected at various points of its course for arresting the rains of heaven and the surface-waters of earth, so jealous is man lest the poor river should have a drop of water too much, or before its time, or should expend what it has too lavishly. In such a hard-worked river the trout and the dace would be idlers and interlopers, and they have long since departed to more leisurely streams: the refuse of the bleach-works or of the dye-house produces an inky, murky mixture which is intolerant of life—of anything, in short, but work.

We are now about to visit a manufactory, the hum of whose machinery blends melodiously with the song of birds, with the rustling of trees, with the gurgling waters of the trout stream, with rural sights and sounds, pleasant to the eye and refreshing to the soul. The paper-maker requires an abundance of pure water; in few manufactures is so much employed, and in none is its quality so important as in the production of fine paper. To attempt to carry on this manufacture with the coloured or mineralized water of peat or iron districts would be hopeless. Paper-mills may be situated almost anywhere except where other mills abound; and hence they are widely scattered, inasmuch as pure streams are happily more common than mines and collieries. Hence, too, water-power has continued to be the prime mover in these mills, more than any other; although many mills have outgrown the capabilities of their streams, and have added the steam-engine to their works.

Linen rags were selected as the material for writing and printing-paper, as being the most worthless of all refuse; and such they continued to be so long as the demand for writing and printing did not exceed the supply furnished by the whole wear of linen in the same country. But the English, the French, and the Dutch have long since required more paper than their worn-out clothing can supply; so that they have to import rags, while the exportation of rags from France, Belgium, and Holland is forbidden by law. The consumption of paper in England is five or six times that of linen, so that by far the larger supply of our rags is imported.

The first operations of the factory are dirty and unpleasant. The rags arrive in this country in a very impure state, and they have to be *sorted*, cut into pieces of about an inch square, buttons to be removed, and seams placed apart by themselves. The rag-cutter stands before a grating, through which the dirt and dust pass, while a sharp knife, fixed with its edge away from the workwoman, is used to divide the rags (fig. 246). The divided rags are thrown, according to their quality, into boxes at the side.

The second operation, called *dusting*, is performed in cylindrical wire cages, inclosing a revolving axis, from which spokes proceed, and the rapid motion of this axle agitates the rags so as to shake out their dust into the wooden case which incloses the cage. *Boiling* is the next operation, for which purpose the water in which the rags are immersed is mixed with lime or caustic soda.

The fourth operation is *washing*, in which the rags are partly reduced to *pulp*, by being passed between a fixed set of cutting edges and another set projecting from a revolving cylinder, called the *roll*, the upper part of which is shown in its position in the trough (fig. 249), while the appearance of the engine is given in fig. 247. The trough is divided into two parts by a partition in the middle; and the roll is furnished with a wooden covering, like that of the paddle of a steamer, to prevent the water and the rags from being scattered about. The motion of the roll draws the rags through between its own cutters and the fixed ones beneath, and then, turning them over a ridge, keeps them and the water in constant circulation round the central partition. The dirty water constantly overflows into a waste pipe, which is covered with wire-gauze to prevent loss of fibre, while fresh water enters by a pipe shown in both figures. In this engine the rags are reduced to what is called *half-pulp*, or *half-stuff*. The colour is such as we recognise in whity-brown paper; but by placing the stuff in a weak solution of chloride of lime, it is changed to a snowy whiteness. The action of the chlorine, however, is to impair the strength and durability of the fibre; so that wherever great durability is required, as for the books printed at the Oxford University Press, or for the paper for Government statistical records, it is preferred unbleached.

The sixth operation is a repetition of the fourth. The pulp is passed through an engine, now called the *beating-engine*, which is identical with the washing-engine, except that the cutting-blades are closer together and more numerous, and the roll revolves quicker.

Such is the material for making paper. If the operation is to be performed by hand, it is mixed with water in a vessel called the *stuff-chest*, from which it flows through a strainer, to separate knots or lumps, into a vessel called the *vat*, which contains a small stove or steam-pipe for keeping the mixture of pulp and water warm, together with a revolving wooden agitator for preventing the pulp from subsiding to the bottom. The sides of the vat are furnished with broad shelves, and the one at which the man works is called a *trepan*. Sheets of paper are formed by *casting* the pulp in a *mould*. The mould may be *laid* or *wove*, and the paper bears the name of the mould which produces it. Each mould consists of a wooden frame filled with wire like a sieve (fig. 248); in the laid mould, the wires are stretched across in one direction only, fifteen or twenty in an inch, and stiffened by thin bars of wood, crossing them at intervals of an inch and a half or less, while a stronger wire runs along each bar, and to which the other wires are fastened: impressions of both kinds of wire are seen in the paper. In wove moulds, the wire is woven into wire cloth of from forty-eight to sixty-four wires in an inch each way; this leaves the paper only slightly granulated

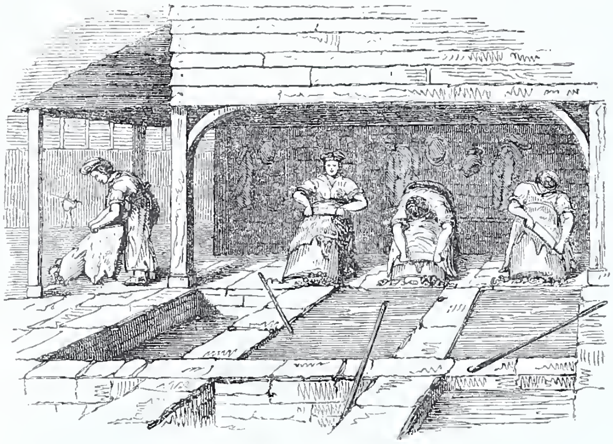
with no distinct lines. Each mould is furnished with a thin frame called a *deckle* (fig. 248), which is placed upon the wires within the ledge formed by the outer frame fitting very accurately, and keeping the moulded sheet to its exact size. The maker, who is called the *vat-man* (fig. 250), dips the mould with the deckle upon it into the mixture of pulp and water, lifts it out with a gentle shake and careful levelling, to equalize the thickness of the sheet of liquid, holds it steadily for a few seconds to drain off the water, when he slides it along the trepan to his fellow-workman, called the *coucher*, at the same time removing the deckle to place it on another mould, in which he makes another sheet. However simple this operation may appear, it is really very difficult to take up 1, or $1\frac{1}{2}$, or 2 oz. of pulp, and spread it equally over one of these moulds, so that the water in draining off may enable the filaments to combine or *felt* together, so as to form an even sheet, and all the sheets be of the same weight. Not only does the vat-man do this, but he will even produce two sheets at one operation in the kind of mould represented in fig. 248. The *water-mark* in the paper is formed of thin wire, sewn upon the wires of the mould, and the impression is produced by rendering the paper where it lies on it thinner and more translucent. The coucher, who receives each sheet, from the vat-man, on the mould with a bare margin of wires all round it where the deckle was laid, turns the whole over upon a piece of felt, an inch or two larger than the sheet in every direction. To this the newly-made paper adheres; and he returns the mould to the vat-man and receives the other mould with a new sheet upon it; but before taking this up from the perforated board on which the vat-man leaves it to drain, he places a second felt over the previous sheet, and upon this turns over the mould and deposits the next sheet. Thus two moulds, but only one deckle, are in use at each vat. The work proceeds until the number of felts and sheets of paper piled up amounts to what is called a *post*, usually 144 sheets, or six quires. The post is now transferred to a screw press, where it is subjected to strong pressure, and remains there until a second post is ready, when it is taken out, and a third workman, called the *lifter*, separates the sheets from the felts. In this way the three workmen—the vat-man or dipper, the coucher, and the lifter, will sometimes produce twenty posts, of six quires each, of moderately large paper in a day.

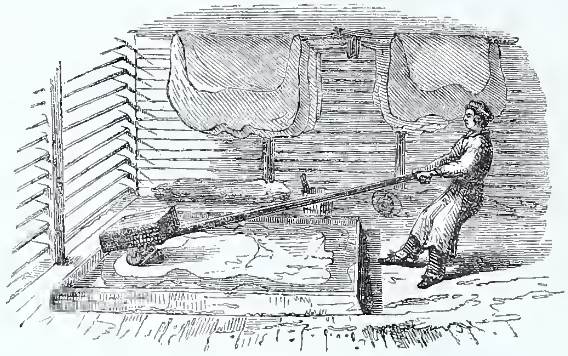
The next process is *wet-pressing*, in which the lifter piles eight or ten posts in one heap; and the sheets being now in contact with each other, instead of with the felt, become much smoother, and, on being removed from the press, can be handled without fear of tearing. For the finer kinds of paper the pressure is repeated after the heap has been re-arranged, by a process called *pack-parting* or *exchanging*, in which the sheets are re-arranged in such a way that none may be next the same sheet as before. The sheets are now removed to large lofts, where the paper is hung upon hair lines to dry. When dry, it is called *water-leaf*, and will absorb liquids freely like blotting-paper. To enable it to be written on, it is *sized*, or passed through a solution of gelatine, containing a little alum, or the size may be mixed up with the pulp in the beating-engine, in which case a compound of flour, rosin, and soda may be used. After the sizing and second drying, the paper is finished by various smoothing operations called *surfacing*. In *hot-pressing*, each sheet of paper is placed between two glazed cards or press-boards, and these between thick smooth plates of cast iron, that have been heated in an oven. A pressure of about 100 tons is then applied, the effect of which is to give a beautiful finish to the paper. The other mode of surfacing is called *milling* when performed between plates, and *rolling* or *calendering*, when the paper itself touches the rollers. The plates may be of copper, of zinc, or of card, each giving its peculiar gloss. It is then passed between rollers at least three times with the paper between them. The highest possible gloss is called *glazing*, and this is produced by passing the paper many times through the roller mill. The process resembles calendering, already described (see fig. 139).

The operations of the paper-maker, such as we have described them, still apply to the finer descriptions of paper; but they are inadequate to the supply of that vast amount of printing-paper which the intelligence of the age, fostered by steam-printing machinery, requires. The inventor of the *paper-making machine* did not set to work to imitate the proceedings of the dipper, the coucher, and the lifter, so much as to see how he could produce cheap and useful paper. Instead, therefore, of making a small wire mould or sieve receive the liquid pulp at one place and carry it along to another, and there deposit it when sufficiently drained and solidified to lie on the felt, and then return the empty mould for another sheet,—instead of this interrupted and fragmentary kind of action, he conceived the idea of a continuous or endless web of *wire-cloth* (figs. 251, 252), stretched over two or more revolving rollers, receiving pulp from the vats (shown at the right-hand extremity of each figure). As the wire-cloth is thus constantly travelling forwards, draining the water away in its progress, it arrives at a point where the wire-cloth turns over its extreme roller, and the web of pulp is sufficiently coherent to be taken up by a felt or blanket, which carries it on with precisely the same speed as the wire gauze, passing the pulpy mass through rollers with gradually increasing intensities of pressure, until the paper arrives at the *drying cylinders*, which, being heated by means of steam, drive off the superfluous moisture, and the finished paper is received on a revolving reel in one continuous roll of any desired length, or it passes at once to a *cutting-machine* (shown separately, fig. 253), where it is divided into sheets of the required size.

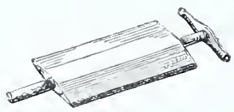
We cannot give more than this general notion of the paper-making machine, without the assistance of more precise drawings than the pictorial forms with which we have to deal; but we may just refer to a few members of the machine which are essential to its well-being. The stuff flows out of the vat through an ingenious *knotter* or *strainer*, for keeping back knots, and yet allowing the linen fibres, which sometimes approach a quarter of an inch in length, to pass through, and not lie across and choke up the apertures. Then there is a contrivance for giving a rapid jerking motion to the wire gauze, to facilitate the draining and equable distribution of the fibres. But as the water that passes through carries with it some of the fibres, it is collected below by a *save-all*, and is lifted by a *Persian wheel*, or wheel of buckets, to a sufficiently high level to flow back into the straining troughs. The edges of the paper on the wire gauze are limited by *deckle straps*, which serve the same purpose as the deckle to the paper-maker's mould (fig. 248). The draining and consolidation of the film on the wire-cloth is further assisted by allowing a portion of the wire-cloth to pass over the open tops of a couple of boxes, the air of which is exhausted by means of three small air-pumps. The pressure of the external air on the paper-film carries much of its moisture into these boxes, and greatly consolidates the layer; so much so, that at this point the pulp visibly changes into paper. Between the two boxes an embossed or perforated roller, called a *dandy*, impresses on the half-solidified film any water-mark or other imitation of the peculiarities of the old hand-made paper.

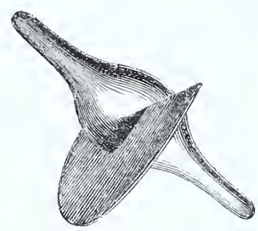
In conclusion, we may refer to the *envelope-folding machine* (fig. 254), the rapid motions of which facilitate the postal arrangements of the day, which, in the year 1857, had to deal out to the inhabitants of these islands not less than 504 millions of letters.


255. LIME PITS.—UNHAIRING HIDES.

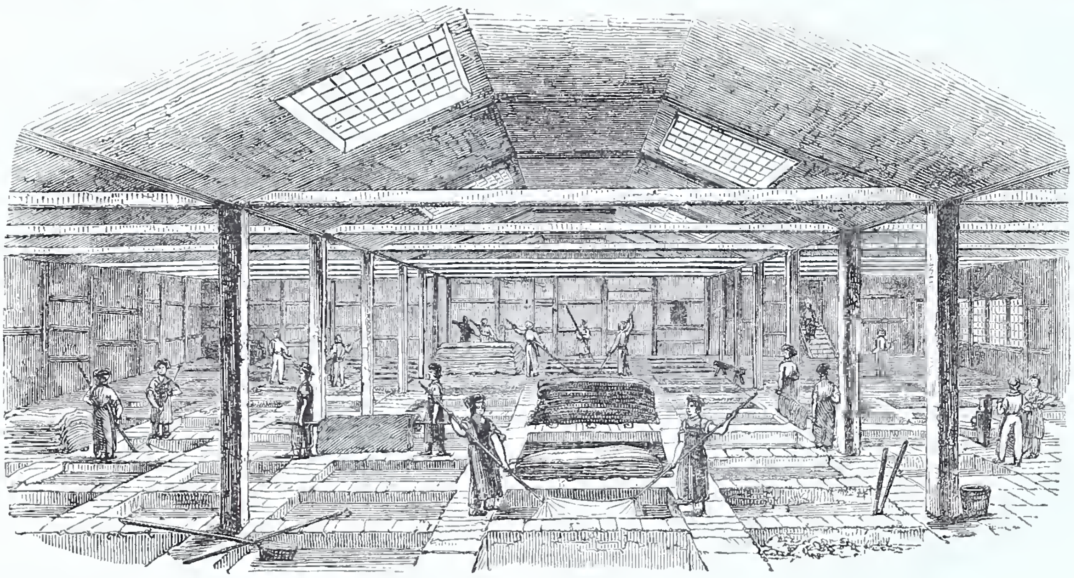

256. FINISHING HIDES.


257. THE BEAM-MAN.


258. CURRIER'S KNIFE.

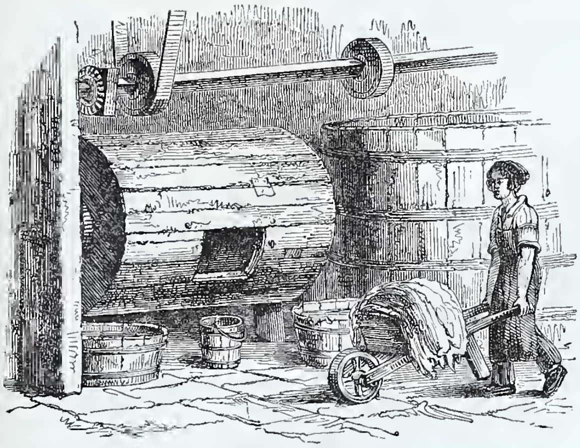

259. HALF-MOON KNIFE.


260. STAKING TAWED LEATHER.


261. THE TAN PITS.

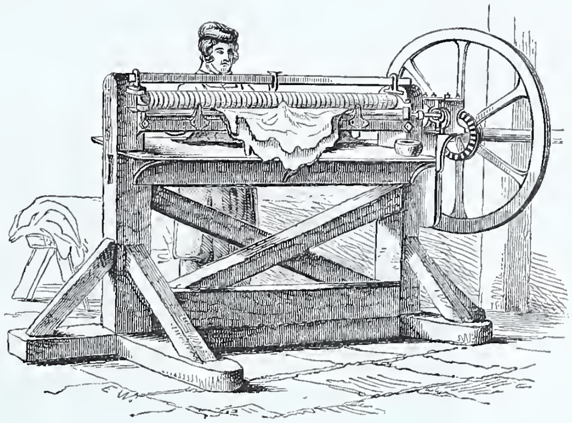

262. THE SUMACH-TUB.


263. FINISHING THIN LEATHERS.

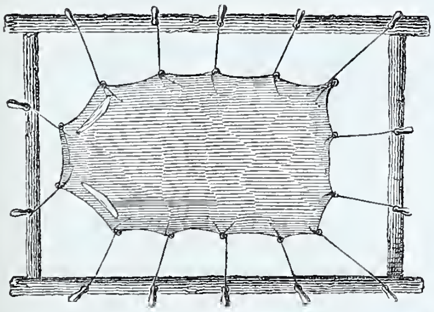


264. TAWING DRUM.

265. SCRAPING.

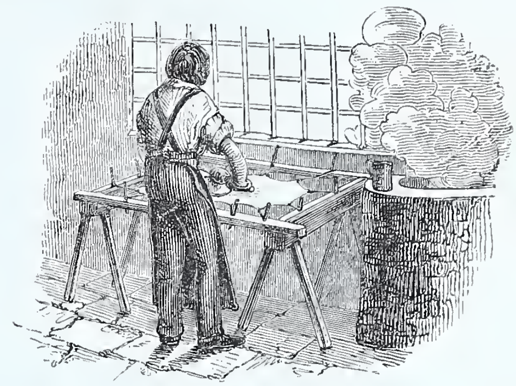


266. SKIN-SPLITTING MACHINE.

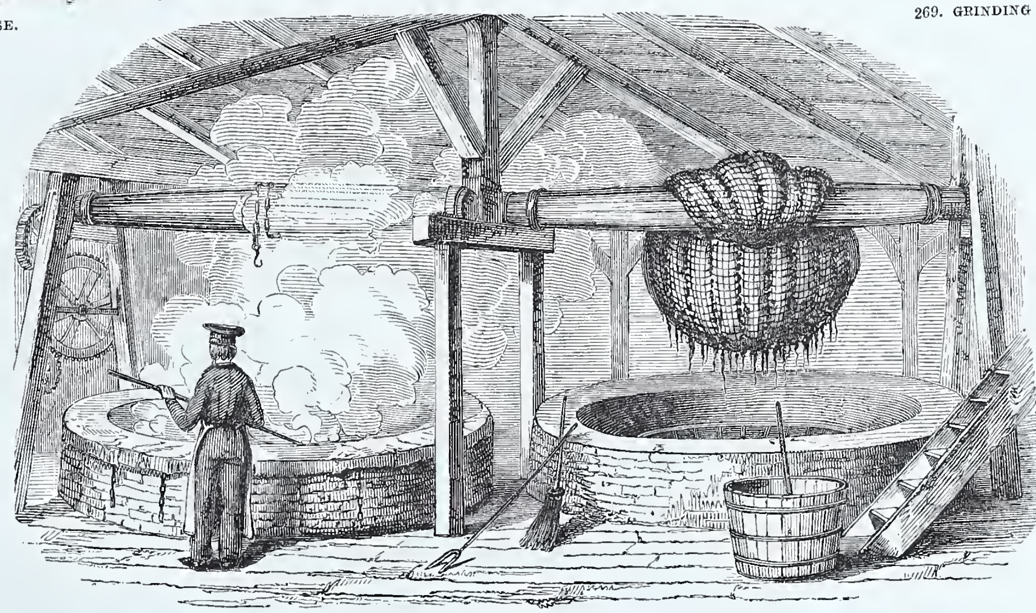


267. HERSE.

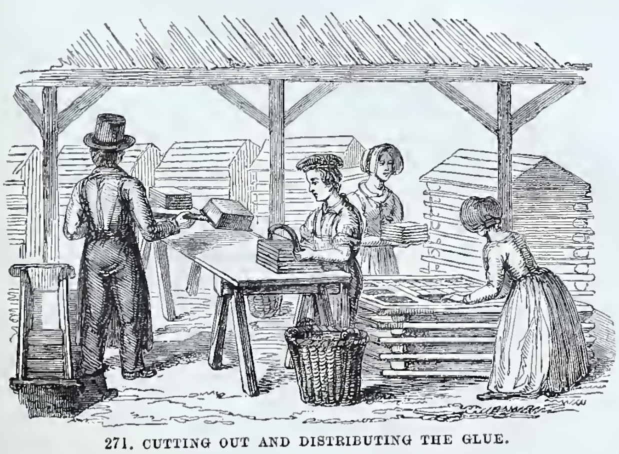
268. SCOURING.



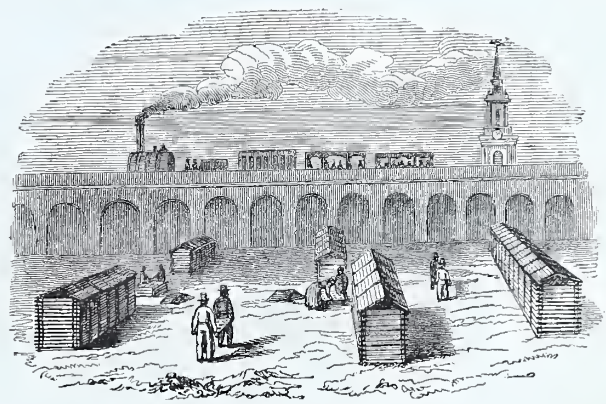
269. GRINDING AND DRAINING.



270. GLUE BOILING.



271. CUTTING OUT AND DISTRIBUTING THE GLUE.



272. GLUE-MAKER'S FIELD AT BERMONDSEY.

XVII.—LEATHER.

In a rude state of society, the skins of animals caught in the chase would be likely to form the clothing of man; but in drying, they would shrink and become horny, and when exposed to moisture, putrid. Hence the art of making a hard, unyielding substance *lith* or pliant, gave rise to the old Saxon term *lither*, or leather. There are various methods by which this change is brought about, and these we must briefly notice.

The hide or skin of an animal consists of the *epidermis* or *cuticle*, which is covered with hair or wool; below this is the *reticulated* or *net-like* tissue, and then comes the *dermis*, *cutis*, or true skin, which is next the flesh. The cutis is alone capable of forming leather; so that the other two must be got rid of, before the manufacture of leather can be commenced. For this purpose, the hides or skins are put into a mixture of lime and water; and in the course of two or three weeks, the lime dissolves the hair-sheath, and combines with the fat of the hide to form an insoluble soap. The skins are then taken out and scraped upon a semi-cylindrical table, called the *beam* (fig. 255), with a curved two-handled iron scraper, called the *unhairing-knife*. The hair comes off readily, and leaves what is called the grain of the skin. A sharp *fleshing-knife* is then passed over the inner surface of the skin, to remove the flesh and the fat. In some cases, the skins are not put into the lime-pits; but are hung up in a *smoke-house*, which is heated by means of a smouldering fire. Here the hides begin to ferment, and the hair becomes loose. This is called *sweating*. Steeping the skins in dilute acids has a similar effect. The stoutest kinds of skins are called *butts* and *backs;* the lighter ox hides are termed *hides;* while the lighter kinds of leather are made from skins. After the latter have been in the lime-pit, they are exposed to an alkaline solution, consisting of the dung of hens, pigeons, and other domestic birds, which renders them soft, and gets rid of the lime.

The true skin consists almost entirely of *gelatine* or *glue:* if this be put into a solution of certain vegetable substances, containing a chemical principle known as *tannin*, the skin will separate that substance from the liquid; and, by combining with it, form leather. This is what is done in the *tan-pits* (fig. 261). The hides are placed flat in these pits; and a quantity of powdered oak-bark (the most important tanning material in common use) being placed between them, water is let in, which forms a solution with the bark, called *ooze*. The skins are frequently turned, taken out and left to drain, or *handled*, as it is called, and placed in pits containing ooze, gradually increasing in strength; until, in the course of from nine to fifteen months for strong hides, the whole of the skin or dermis has disappeared, by the gradual combination of the gelatin and the tannin. When the tanning is complete, they are rinsed with water, and hung up in lofts to dry. Once or twice during the drying, the skin is placed on a cylindrical horse, and *struck* or smoothed with a triangular steel knife; the surface being occasionally sprinkled with a bunch of butchers' broom dipped in water. This brings what is called the *bloom* to the surface, and produces that peculiar colour which we see in new sole leather. The hides are next condensed under a weighted roller (fig. 256), and are then ready for the market.

The lighter hides or kips, and that description of leather used by the shoemaker, coach-maker, harness-maker, &c., are finished by the currier, who throws the skin over an upright wooden beam, faced with lignum vitæ (fig. 257), and shaves it on the flesh side with a knife (fig. 258), the edge of which has been turned over at right angles to the broad blade. By this means, the skin is reduced in thickness, and the rough flesh side made tolerably smooth and even. The skin is then thrown into water, and, after soaking, is stretched upon a large table, and worked with a tool called a *stretching iron*. Lumps and inequalities in the leather are thus got rid of, and the skin is extended; both sides of the skin are smeared with a mixture of cod-oil and tallow, after which it is worked with a number of tools preparatory to laying on the *colour*, or blacking, which is a mixture of oil, lamp-black, and tallow. A black colour is also produced by applying to the skin a solution of sulphate of iron; which, uniting with the gallic acid of the tan, forms an ink dye. The immense demand for thin leathers, such as *white* and *dyed* leather for gloves, *morocco* for coach lining, book-binding, pocket-books, &c., *roan* for slippers, &c., *skiver* for hat-lining, and *shamoy*, or wash leather, is supplied by various processes. White leather is not tanned, but *tawed;* or treated with a mixture of alum and salt in a large drum (fig. 264), and after having been washed and dried, the skins are returned to the drum, where they are churned with a paste of the finest wheat flour, and the yolks of eggs. This produces the glossy finish and softness of white kid, which is further developed by working it upon a rounded iron, mounted upon an upright beam (fig. 260).

Preparatory to tawing, &c., the skins must be freed from hair, wool, grease, &c.; and when thoroughly cleansed, they form what is called *pelt*. Sheep-skins, from which imitation morocco is prepared, are divided or split by means of a machine (fig. 266). It consists essentially of two rollers; the lower one solid, and the upper one composed of rings. These cylinders rotate slowly; and between them, but not in contact with them, is a knife which is made to move rapidly to and fro along the length of the cylinder. Standing on the opposite side to the knife, the man spreads out a skin on the lower roller, when it is dragged forward against the edge of the knife, and divided; one half going above, and the other below the blade. The rings which form the upper roller, allow of adjustments depending on the varying thickness of the skin. Sheep-skins are sometimes split into three; the grain side being used for skiver, &c., the middle for parchment, and the flesh side for glue.

Goat-skins tanned with sumach and dyed on the grain side, form the best morocco. Sumach consists of the powder of the leaves and young branches of shrubs growing in the south of Europe, and known as *Rhus cotinus*, *Venus sumach*, or the wild olive, &c. The pelts are made up into bags, and these, being filled with a solution of sumach, are placed in the *sumach-tub* (fig. 262), where they are agitated by a stirrer moving backwards and forwards. After about three hours, they are taken out, and piled on a shelf at the side of the vat; their mutual pressure causing the sumach to escape through the pores, and thus assist the tanning. After being treated with a stronger solution for about nine hours, the tanning is complete. When dry, they are finished by various processes, such as scraping and rubbing and oiling; the grained or ribbed appearance peculiar to morocco being given by rubbing the surface with a ball of box-wood furnished with ridges (fig. 263). The skins are dyed in the form of pelt, with a mordant of tin or alum, and cochineal for red, indigo for blue, orchil for purple, &c. *Dressing in oil*, or *shamoying*, consists in soaking the skin in water, and then rubbing oil or grease into its pores. As the water evaporates, the fat combines with the fibres of the skin, and converts it into leather. This process was originally applied to the skin of the chamois goat, and gave rise to the term *chamois* or *shamoy* leather. This kind of leather will bear washing, even when dyed, and is hence also called *wash leather*.

The demand for leather is large and constant: it forms an important part of our clothing, furnishes harness to horses, linings to carriages, covers to books, enters into the construction of various engines, machines, and articles of household furniture; so that we need not be surprised to find the manufacture in this country second in importance only to that of cotton and of wool, and about equal to that of iron. In the year 1856, the value of our exports in leather amounted to 1,757,063*l.* sterling.

XVIII.—PARCHMENT.

PARCHMENT must always be interesting for the many services which it has rendered to literature. Had it not been for the comparative indestructibility of this substance, the many wise and beautiful compositions of the ancients, which exerted so much influence in recovering Europe from the oppressive influences of the dark ages, could not have been transmitted. Even when the rude hand of ignorance erased the writing for the purpose of engrossing some superstitious legend on the parchment, it has still been possible to trace the marks of the original writing, beneath the monkish legend. In this way, valuable works apparently lost to the world have been recovered.

The skins of most animals are adapted to the making of parchment; but as most of them are more valuable for making leather, the sheepskin, so abundant in this country, is commonly employed by the parchment-maker. The skins of calves, kids, and dead-born lambs furnish the finer kind of parchment known as *vellum.* The skin of the ass, the calf, or the wolf furnishes the stout parchment used for drum-heads; ass's skin also supplies the parchment for battledores. The skins are unhaired either by sweating, or by steeping in lime, and this alkali also combines with the fat. The skin is then stretched upon a wooden frame, called a *herse,* in the manner shown in fig. 267, and a man, called the *skinner,* furnished with what is called a *half-moon knife* (fig. 259), scrapes the skin so as to get rid of fleshy substances, dirt, and slime. The herse is then placed upon *tressels* (fig. 269), is sprinkled on the flesh side with powdered chalk or slaked lime, and well rubbed with a flat surface of pumice-stone; this is called *grinding.* The grain side of the skin is ground with pumice only. The knife is next passed over the skin, which produces a whitening effect, called *draining.* Fine chalk is next rubbed over both sides of the skin, and it is set aside to dry. The skin is next cut out of the frame, and a man, called the *parchment-maker,* stretches it upon a frame, called a *sumner,* and passes over the grain a sharp circular knife, paring off about half the substance of the skin, and leaving a smooth surface. Should any roughnesses appear, they are smoothed down with pumice, and the holes, if any, are closed by cutting the edges thin, and attaching small pieces of parchment with gum water. The green parchment used in bookbinding is coloured by means of verdigris. White of egg or gum water is rubbed over to give the polish.

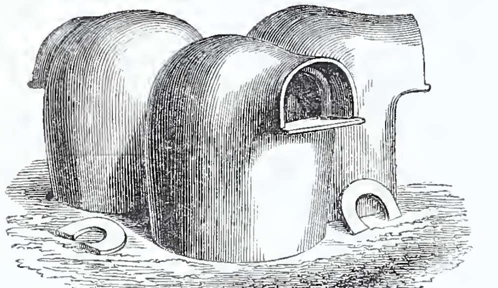
XIX.—GLUE.

Gelatine, the basis of portable soup, is made by boiling in water certain animal tissues and the waste residue of parts of animals which have served for food, together with the clippings of hides, hoofs, horns; feet of calves, cows, sheep, pigs; various membranes, and the waste particles in the carving and turning of ivory, &c. *Isinglass* is prepared from the membranes of different species of fish, especially of the sturgeon family. *Glue* is obtained from the same sources which furnish gelatine, assisted by the coarser refuse of the knacker's yard, the refuse from the skins of cats, dogs, &c.

When the water in which these substances have been boiled is allowed to cool, it forms a tremulous jelly, called *size.* When the size is purified by means of sulphurous acid, and is dried in thin layers, it is used as a substitute for isinglass. Without such purification, the dried slices form glue.

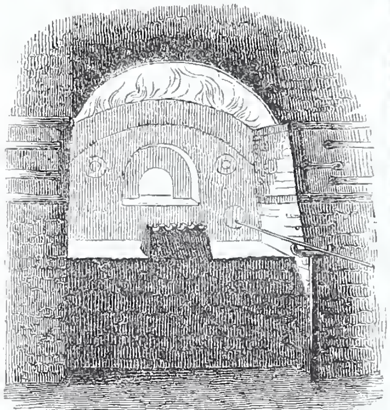
When the animal refuse arrives at the glue-maker's, it is steeped in lime, washed in water, and placed on hurdles to dry. The glue-maker is not anxious to get rid of all the lime, since by exposure to the air it forms chalk, and he does not object to the presence of that substance in the glue. The boiling is carried on in a large iron cauldron; but the animal matters are not thrown into the water of the cauldron, or they would be liable to become attached to the sides and burn. A large rope bag or net is placed within the cauldron, and into this the animal matters are thrown: water is admitted, and is gradually raised to the boiling point; and as the clippings, &c., subside, fresh quantities are added, with occasional stirrings. A portion of the water is taken out from time to time; and when this cools into a clear jelly, the mouth of the bag is closed with cords, and the bag itself is wound up and made partly to coil round a beam (fig. 270), where it is left to drain. The contents of the bag are boiled a second and a third time for size, and once more for adding to a new bagful of animal matters; and when everything soluble has thus been boiled out, the contents of the bag are sent to the manufacturer of manures, who has risen into importance under the present improved and complicated system of agriculture. The solution of glue in the cauldron is run off into a *setting-back,* where it is clarified, and then run off into long narrow wooden coolers: when cold, it is cut into square cakes, and the cakes into slices, by means of a brass wire (fig. 271), and the slices being placed upon nets, stretched in wooden frames, are removed to the *glue-maker's field* (fig. 272), and are placed in piles under a movable roof. The pile is taken to pieces two or three times a day, and the glue is turned to prevent it from sinking into the net, which, as it is, leaves its well-known mark upon the surface. The drying of glue is rather an uncertain operation in our variable climate. When about three-fourths of the moisture has evaporated, the drying is completed in lofts. Some weeks or months may even elapse before it is sufficiently hard for the market. During all this exposure to the air, the surface becomes dirty and mouldy. The glue is therefore *scoured* (fig. 268) with a scrubbing-brush and hot water, and lastly dried at a stove-heat.

In the Great Exhibition of 1851, large quantities of gelatine for ornamental purposes were shown in the French department, among which we may notice the thin white transparent sheets of *papier-glacé* or *ice-paper* for copying drawings, dyed, silvered, or gilt gelatines for various purposes, among which was the making of artificial or fancy flowers. There were large groups of gelatine flowers, richly coloured, and closely imitative of nature; but the glittering, semi-transparent material gave them all a drenched appearance.

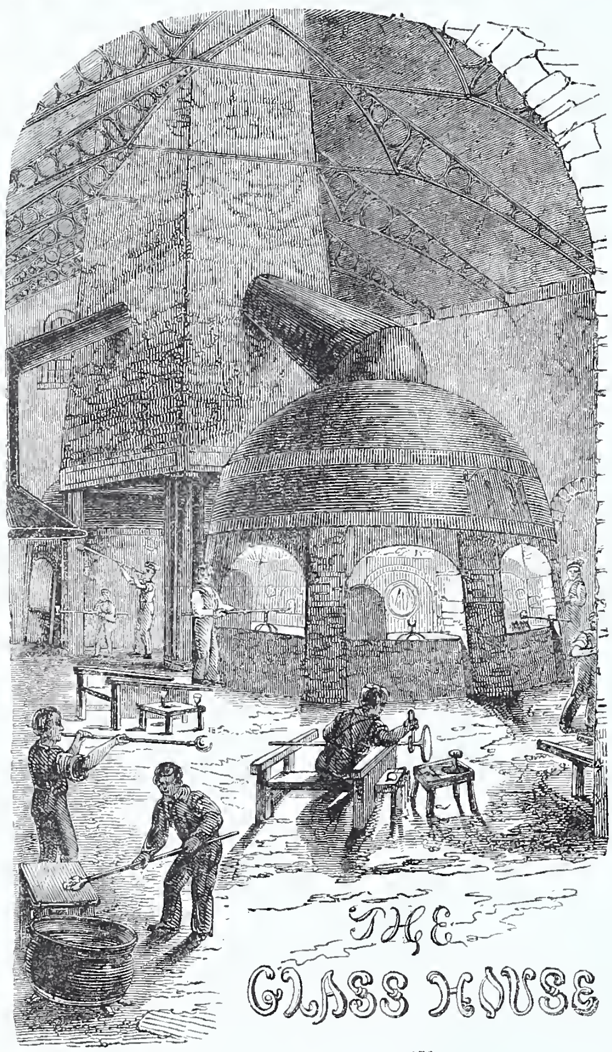


273. GLASS POTS.

274. GLASS-BLOWER AT WORK.

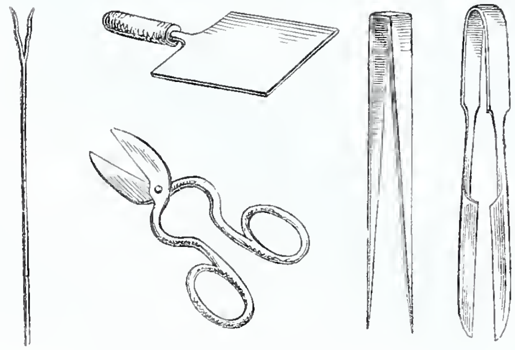


275. MOUTH OF THE FURNACE.

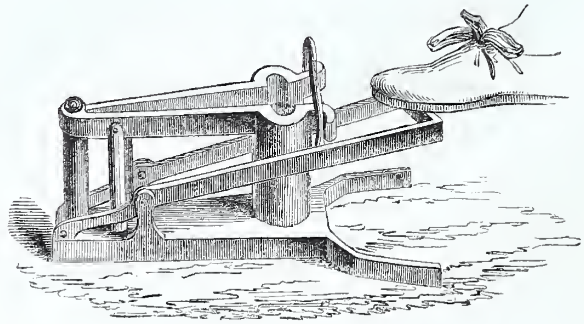


276.

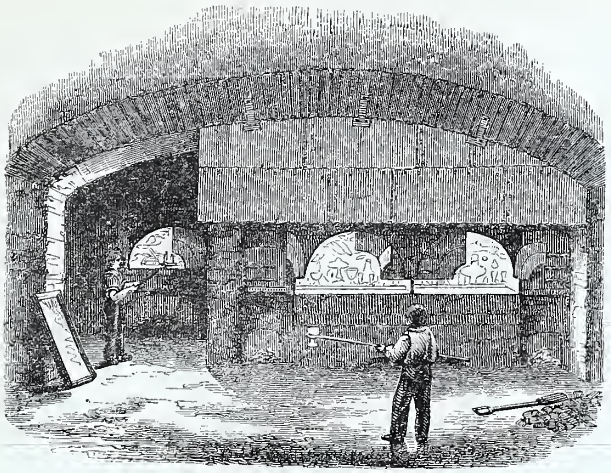
277. MAKING BOTTLES.



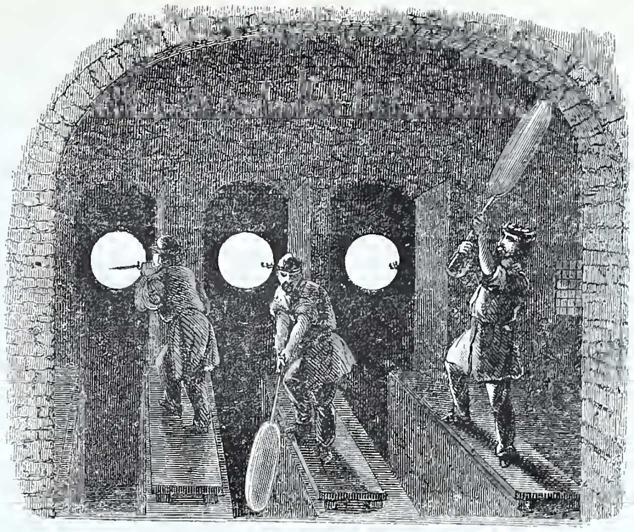
278. GLASS-BLOWER'S TOOLS.



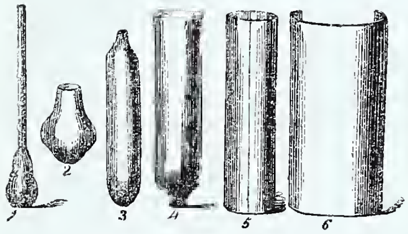
279. FLINT-GLASS BOTTLE MOULD.



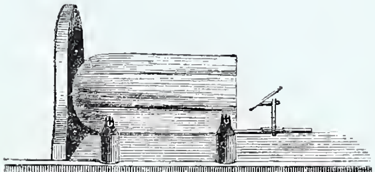
280. THE ANNEALING OVEN.



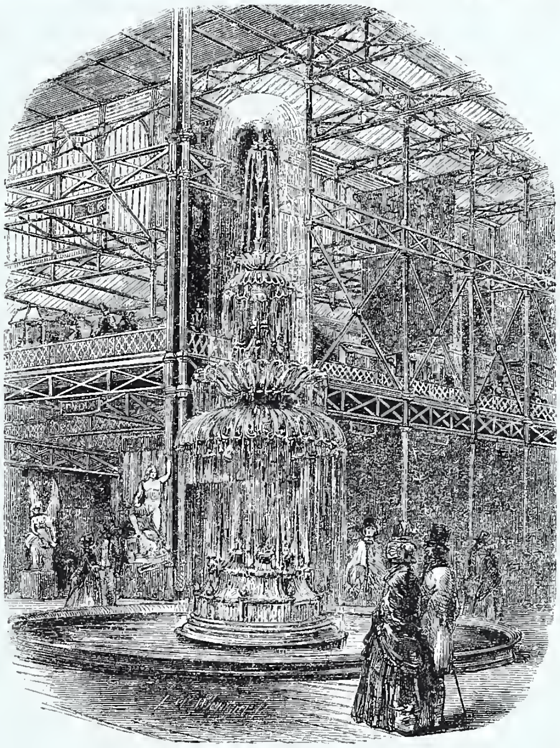
281. BLOWING AND SWINGING CYLINDER GLASS.



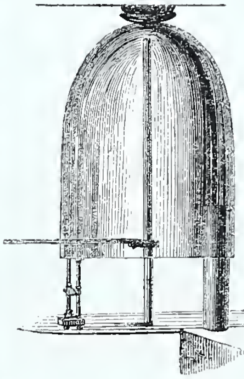
282. STAGES OF CYLINDER GLASS.



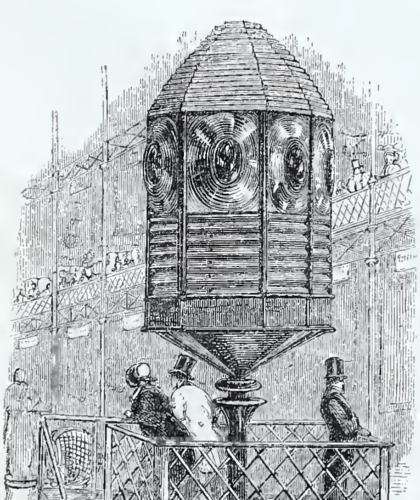
283. GLASS SHADE FRAME.



284. THE GLASS FOUNTAIN.



285. GLASS SHADE FRAME.



286. LIGHT HOUSE.

287. MASS OF ROCK CRYSTAL.

288. GLASS SHADES.

XX.—GLASS.

In the eighth century, Wilfrid, Bishop of Worcester, substituted glass in the windows of his cathedral for the heavy wooden shutters, which were in common use, not only in his time, but for eight centuries later. The people gazed with astonishment on a substance which filtered the light from the wind and the rain; and were disposed to attribute the production of the transparent material to the powers of magic, rather than to the wit of man. And truly glass is a beautiful and a wonderful substance. Produced from materials which are themselves opaque, it can be moulded, blown, or worked into transparent vessels of large size, great strength, and beautiful form. A vessel of glass is the proper receptacle for that best of beverages, pure water, for in it the eye is at once satisfied of its purity. The numerous articles of glass in domestic use promote cleanliness and comfort; for nothing is so offensive to the eye as dirty glass. Even the mirrors which adorn our walls help us to preserve our persons in neatness and cleanliness. By means of glass the eye of age regains something of its youthful vigour: by means of glass the two extremes of the vast and the minute unfold their wonders in the telescope and the microscope: by means of glass the natural philosopher and the chemist have wrested innumerable secrets from nature: by means of glass, the solitary lamp of a light-house marks out the distant horizon with its luminous fingers, and warns the navigator of rocks and shoals.

Glass is a compound of siliceous sand, with a mixture of an alkali and an earthy base, or with the oxide of one of the heavy metals, such as lead. The sand acts the part of an acid (silicic acid), and, by combination with the base, forms a class of compounds known as *silicates*. Thus *flint* or *crystal* glass is a silicate of potash and oxide of lead; *common window* or *English crown* glass, and *plate* glass, are a silicate of soda and lime, or a silicate of potash, soda, and lime; while coarse green *wine-bottle* glass is a silicate of soda, lime, alumina, and oxide of iron. The use of the lead is to impart brilliancy and fusibility to silicates which, by themselves, would be infusible. Lime and alumina confer hardness, and iron gives a dark colour. Potash and soda also assist the fusibility of glass.

Flint glass formerly obtained its silica from flints, which were calcined and ground. Fine sea sand, as free as possible from iron stains, is now used. The potash is in the form of the carbonate, and the lead in the form of the red oxide. These materials being carefully mixed and sifted, form what is called the *batch* or *frit;* this is melted in pots of refractory clay (fig. 273), hooded over so as to protect the materials from the direct action of the fire; and having a mouth projecting from the furnace into the glass-house. The horse-shoe pieces shown in the figure are for contracting the mouth of the glass-pot when required (fig. 273). A flint glass-pot will contain about eighteen cwt. of melted glass.

Articles in flint glass are first formed by *blowing*, and they are afterwards worked into shape with the assistance of a few simple tools. The *blowing tube* is of iron, from four to five feet in length, with a bore of from one-third of an inch to an inch in diameter. The end of this being heated nearly to redness, it is introduced into the pot of glass or *metal*, as the workman calls it, a portion of which adheres to it; and, by turning it round, he can gather up as much as he requires. He then rolls the glass upon a slab of cast iron, called the *marver*, in order to give it a regular exterior surface, and to produce a regular thickness when expanded by blowing. Applying his mouth to the tube, he expands the glass into a globular shape. When the size of the required vessel has been attained by blowing, a boy dips the end of a solid rod called a *ponty* into the glass-pot; and, gathering up a small quantity of the metal, attaches it to the blown glass, at a point exactly opposite the blowing iron. The latter is now detached by a drop or two of water, which chills and contracts the glass so as to allow the blowing iron to crack off. The workman now seats himself in his chair (fig. 274), rests the ponty on the two sloping arms, and rolls it backwards and forwards; so as to give a rotatory motion to the glass vessel, and proceeds to finish the neck; occasionally holding the vessel in the mouth of the furnace, so as to soften the glass when it has become too hard for working. The tools used are represented separately in fig. 278. The first is merely a fork for carrying the finished article to the annealing oven; the second is a flat surface of wood called a *battledore*, and is used for giving a flat surface to the bottom of vessels; such as a wine-glass. There is also a pair of *shears* for cutting off superfluous metal, finishing the edges of tumblers, &c.; the glass, when at the proper temperature, being as easily cut as leather. The fourth tool, called the *pucellas*, resembles a pair of spring sugar-tongs: this tool is used to open or close the insides of hollow vessels, and to shape the vessel as it is rotated on the inclined planes of the chair, and for many other purposes. The fifth is called a *spring-tool;* it is a kind of tongs used for laying hold of half-formed handles, and for seizing the glass in certain positions. The glass-blower has also a pair of *compasses*, and a *measure-stick*. When the vessel is brought to shape, handles, feet, rings, &c., are attached by welding by contact, which is one of the valuable properties of glass at about a red heat. The various operations of the glass-house are represented in fig. 276. Bottles are made in a mould (fig. 279), consisting of two parts, which fall open, except when pressed together by placing the foot on the treadle. In blowing a bottle, the man gathers up a sufficient quantity of glass upon his blowing iron, inserts the glass into the open mould, presses the two parts together with his foot (fig. 277), and, by blowing, causes the glass to swell out and line the interior surface of the mould.

When glass is rapidly cooled, it becomes so brittle that it is entirely unfit for use. This inconvenient property is removed by the process of *annealing*, or slow cooling. The annealing oven (fig. 280) is a long low arch, hot at one end and gradually cooling towards the other end. As the articles of glass are finished, they are put into iron trays at the hot end of the arch; and, as these become full, they are pushed forward by other trays, until, after many hours, they arrive at the cool end of the arch, and are fit for use.

Flint glass vessels are ornamented by the glass-cutter, who grinds away portions of the glass, by means of an iron wheel, constantly supplied with sand and water. The rough sand-marks are smoothed out by a stone-wheel with water; and the cutting is finished on wooden wheels with rotten stone, putty-powder, &c. The ornamentation of glass is, for the most part, a mistake in art; the material is so pure, the best forms are so simple, and the surface is so exquisitely finished by the heat of the furnace, that the attempt to superadd ornaments usually detracts from these valuable qualities. The idea of the glass-cutter is to increase the brilliancy of the material by forming the surface into facets, and thus rivalling the lustre of gems and precious stones. There may be some advantage in this, if done judiciously; but one of the chief faults of our workshops is that of over-ornamentation.

Crown glass is formed by blowing a globe at the end of the blowing-iron, transferring this to the ponty; and by causing the globe to rotate on a horizontal axis before the mouth of a furnace, it flies open into a large sheet or table with a noise something like that produced by opening a wet umbrella. Another method, known as the *cylindrical process*, is represented in fig. 281. A

quantity of metal being collected at the end of a blowing-iron, as in No. 1, fig. 282, this is blown into the form No. 2, which is elongated by centrifugal force into the form No. 3. The man then forces an additional quantity of air into this elongated vessel, and, applying his thumb to the end of the tube, holds the glass in the furnace as represented in fig. 281, when the imprisoned air, expanding under the heat, bursts open the end or thinnest portion of the glass. The uneven edge is trimmed with scissors, and enlarged with the pucellas, until it is brought to the shape No. 4, fig. 282. The neck is removed by turning a red-hot iron round the part, and allowing a little water to fall on the heated glass. Water is also passed down the length of the cylinder so as to crack it preparatory to opening it; and it is now in the condition of No. 5, after which it is taken to a furnace, placed on what is called a *flatting hearth*, where it is opened, and spread out into flat sheets of glass. The magnificent glass shades represented in fig. 288, some of which are five feet and upwards in height, were formed by this process. If these large shades are to be preserved as such, each one is placed in a *frame* (figs. 283, 285), where, being supported in the one case horizontally, and in the other vertically, a mounted diamond is made to act against the side so as to reduce it to shape, and to the proper proportions.

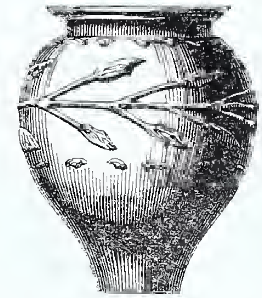
Plate-glass is formed by collecting a quantity of the molten metal in a glass-pot or cistern, and swinging it by means of a crane over a metal table, furnished at the sides with ribs of metal to prevent the glass from flowing off, and also with a roller for rolling it out flat. The cistern is tilted over, and a torrent of melted glass is poured upon the table, producing a very fine effect; when rolled out into a sheet of uniform breadth and thickness, it is pushed off the casting-table upon a wooden platform and so conveyed to the annealing oven, where it remains flat on the floor for about five days. After this, the plate undergoes a laborious system of grinding and polishing before it is fit for silvering.

The application of lenses to light-houses (fig. 286) is an improvement on the old system of Argand lamps and metallic reflectors. In this arrangement there is a single central lamp consisting of four concentric wicks, furnishing a large volume of flame. Round this central lamp lenses are arranged so as to form an octagonal hollow prism, which, revolving round the fixed central flame, gives to a distant observer successive flashes or blazes of light, whenever one of the octagonal faces crosses a line joining his eye and the lamp. The difficulty of making these large lenses sufficiently accurate in form in one piece, led to the suggestion of building up a lens in separate pieces, the result of which has been quite successful.

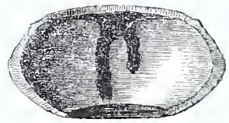
Far more difficult is the manufacture of glass for optical purposes; and the difficulties increase with the size; so much so, that the production of the large object-glass of a telescope free from little specks and inequalities known as *striæ*, *wreaths*, *knots*, *threads*, and *tears*, and imperfections arising from want of uniform density in the glass, is all but impossible. The maker of an object-glass eleven or twelve inches in diameter, recently offered it to the Royal Observatory at Greenwich, for the sum of 1,100 guineas, and the price would gladly have been paid, had the glass been free from defect. We have not succeeded in producing glass of the pellucid clearness of Nature's workmanship, as in the mass of rock-crystal, fig. 287; and we are only conscious of our defects when we come to examine her works, and find it necessary to employ that perfection which she commands in producing them. The glass fountain of the Crystal Palace, fig. 284, may sparkle in the sunshine and cast its rainbow tints around; but such a work is rude and clumsy in the extreme when compared with the exquisite instruments which, while they imitate, vastly extend the powers of that most exquisite of organic structures, the human eye. Some years ago M. Guinand, a clock-maker of Brenets, near Neufchâtel, in Switzerland, succeeded in making disks of flint-glass six inches in diameter, of great purity. He kept his method secret, and only imparted it to his sons on his death-bed. They have since shared it with other persons, and the effect has certainly been to improve the manufacture of optical glass.

289. GREEK VASE.

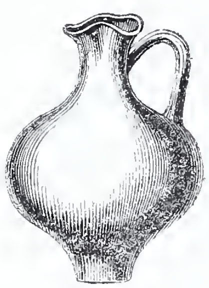
290. INTERIOR OF A TUMULUS NEAR RADEBERG.



291. ROMAN VASE, FOUND AT ZAHLBACH.



292. INDIAN BLACK POTTERY.

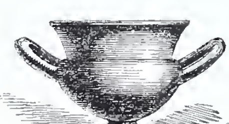


293. VASE FOUND NEAR DIEPPE.

294. ARRANGEMENT OF VESSELS IN A TOMB NEAR CASTEL, IN THE DUCHY OF NASSAU.

295. PURSE-SHAPED VASE, RED AND BLACK.

296. DECORATED URN, FOUND AT COLNEY IN NORFOLK.



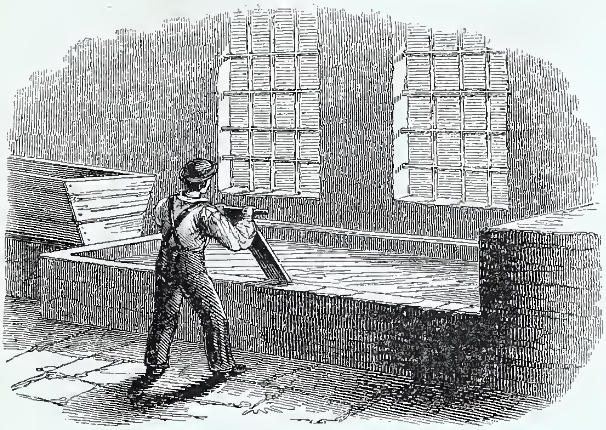
297. RED AND BLACK VASE.

298. ROMAN AMPHORA, DUG UP NEAR LONDON BRIDGE.

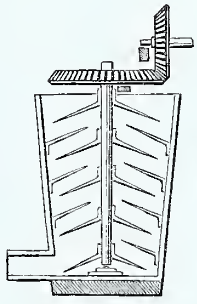
299. VASE FOUND AMONG THE RUINS OF ANTINOE.

300. TUNISIAN POTTERY.

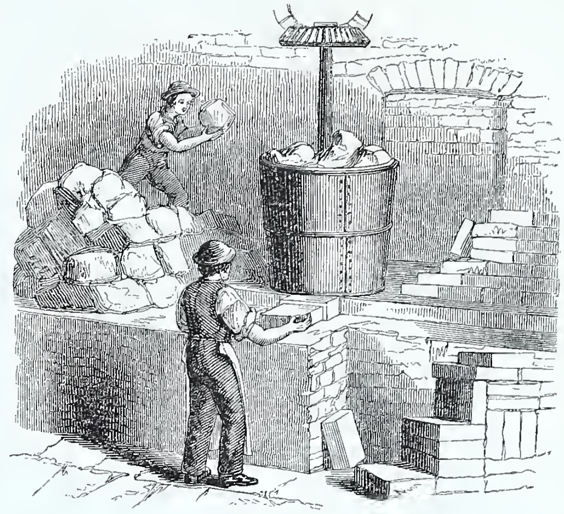
301. ANCIENT URN, FOUND NEAR NORWICH.



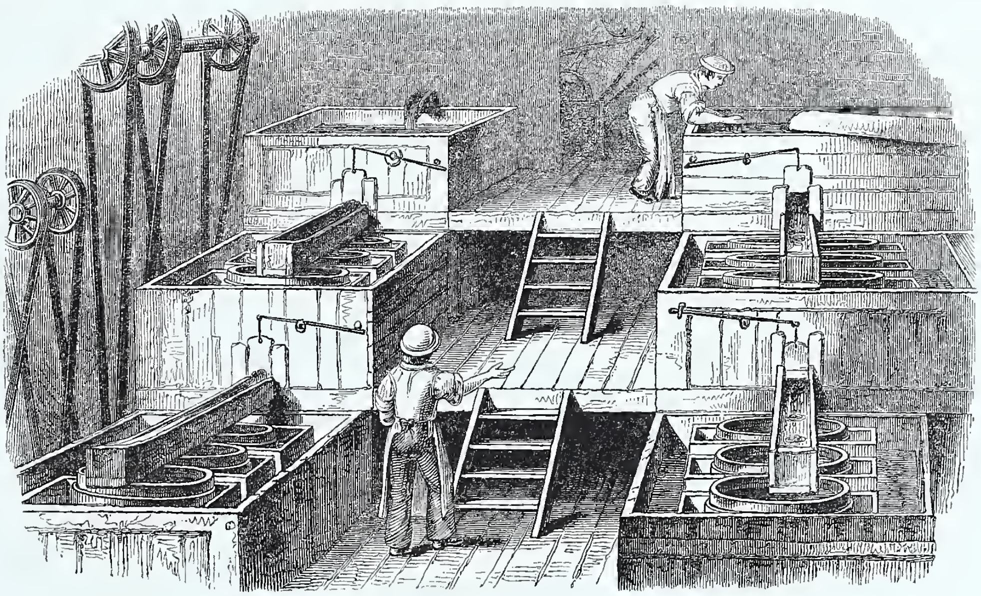
302. BLUNGING.



303. PUG-MILL.

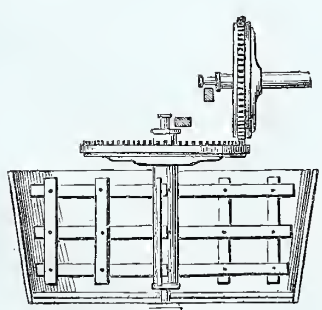


304. GRINDING THE CLAY.

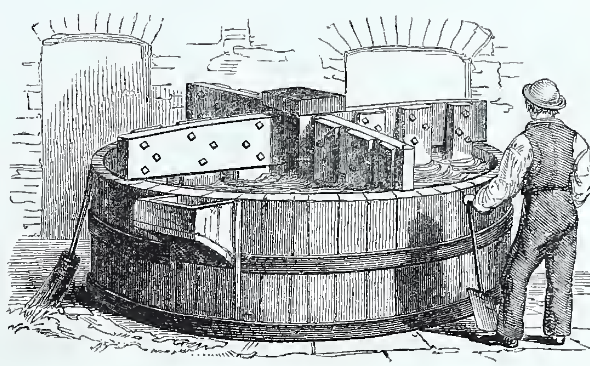


305. MIXING THE INGREDIENTS.

306. FLINT MILL.



307. SECTION OF FLINT PAN.



308. FLINT PAN.

XXI.—POTTERY AND PORCELAIN.

As in digging into the earth we may sometimes turn up the fossil remains of animals and plants which illustrate a former condition of the surface of the globe, so we may also turn up urns and utensils of baked earth which throw light on the condition of its ancient inhabitants, whom the historian has neglected to notice, or has passed lightly by. It is curious that a piece of common pottery ware, which a slight blow might shiver to pieces, should be far more enduring than epitaphs in brass and effigies in bronze; that the mound of earth erected to the forgotten warrior or chieftain should be more enduring than the deeds of kings, pictured on the walls of stately palaces. Monuments of brass and of iron rust away; silver and gold tempt the cupidity of the thief; stone crumbles under the disintegrating effects of the atmosphere; ink fades, and paper decays; but the fictile vase deposited in some quiet receptacle survives the changes of history and of chemistry, and even in its fragments preserves some traces of the hand that moulded it. Fig. 290 represents the interior of one of the green mounds or tumuli so common in the north of Germany, and the kind of vessels found therein. The latter probably contained the ashes of the dead, as no skeleton or bones were found in them; but in many cases the skeleton still remains, with vases at the feet and head, or hanging on pegs from the sides of the tomb. Fig. 294 shows one form of arrangement of vases in a tomb where the body had been burnt, and the ashes deposited in a central urn surrounded by other vessels, the four smaller ones being inclined towards the larger one in the centre; the other vessels were of glass or of pottery, and had contained such liquids as wine, milk, balm, oil, &c. Excavations among the ruins of ancient cities have led to the discovery of innumerable clay records of early nations. Thus Layard discovered a whole library in the palace of Sennacherib, containing histories, deeds, almanacs, spelling-books, vocabularies, inventories, horoscopes, receipts, letters, &c. Altogether about 20,000 of these clay books of the Assyrians have been discovered; and on the impressions of seals on some of the royal muniments may still be traced the marks of fingers, made while the clay was yet moist.

The word pottery is derived from the Latin *potum*, a drinking-vessel; and the earliest employment of earthen vessels was doubtless for the common purposes of domestic use. Many of those dug up in this country are of Roman workmanship, such as the fusiform *amphora* (fig. 298); others owe their origin to a period anterior to the Roman invasion, such as the urn (fig. 301), made of a thick black clay, ornamented with some tool, but evidently not turned: this, together with fig. 296, contained bones, ashes, and charcoal. Roman pottery is distinguished by the greater care in the workmanship and the superiority of the material; the elegant vase, fig. 293, is of this kind, while fig. 291 shows the method of ornamenting in a different coloured clay, such as a flowering branch in white clay on a vessel of the ordinary red pottery. In this respect Greek pottery is pre-eminent, as in fig. 289, in which the figures are red on a black ground. Fig. 299 is a specimen of ancient Egyptian pottery unglazed; and fig. 292, which represents a specimen of Indian black pottery, shows that, as in our own day, a liquid glaze was employed, the specimen proving that a portion of it originally flowed down the unglazed side of the vessel. Many of these ancient forms are perpetuated by Eastern nations at the present day, as will be seen by reference to the ware from Tunis, fig. 300.

Porcelain is only a superior kind of pottery; but it is distinguished by being translucent, while every form of pottery is opaque. The origin of the word porcelain is uncertain: some refer it to *porcellana*, the Portuguese for a drinking-cup; others to the same word in Italian, which signifies a univalve shell of the genus Cypriœdæ, or cowries, having a high-arched back like that of a hog (*porco* in Italian), and a white, smooth, vitreous glossiness of surface. Pottery is grouped as *soft* and *hard*—terms which have reference to the composition of the ware and the temperature at which it is baked; thus, common bricks, earthenware, such as pipkins, pans, &c., are soft; while fire-brick, and crockery, such as Queen's ware, stone-ware, &c., are hard.

The essential ingredients in every article of pottery and of porcelain are silica and alumina, or flint and clay. The pure silicate of alumina is an ideal type not attained even in the finest porcelain, while in the coarser varieties such impurities as iron, lime, potash, &c., are not much regarded, although they give character to the wares. In some cases it is necessary to add to the compound of silica and alumina certain substances for rendering those refractory materials more fusible. Soft pottery is composed of silica, alumina, and lime; it is usually fusible at the heat at which porcelain is baked, and can be scratched with a knife or a file. Stone-ware is a kind of coarse porcelain, and is composed of silica, alumina, and baryta. Hard porcelain contains more alumina and less silica than the soft; it is fired at a higher temperature, and is more dense. Soft porcelain contains more silica and alkaline fluxes than the hard; it can be readily scratched with a knife, and cannot resist a very high temperature.

Glazes form an important part of fictile ware. When the article has been properly shaped, and passed once through the fire, it forms a hard porous substance, named *biscuit*. *Glazing*, or *glassing*, consists in covering the ware with a thin layer of glass, which deprives it of its porosity. In the translucent wares, such as fine porcelain, the glaze must resemble in character the body of the ware, only it must fuse at a lower temperature.

In such a case, the biscuit being white, the glaze must be so also; whereas in pottery-ware the paste is contaminated with protoxide of iron, which, under the oxidizing influence of heat, becomes converted into the red peroxide, the result of which is a red biscuit, which is concealed by opaque or coloured glazes. These do not, as in the case of fine porcelain, form part of the ware itself, but constitute a distinct layer on its surface. It will be understood, then, that in the case of porcelain and fine pottery the wares pass twice through the kiln: in the first firing they are converted into biscuit; they are then coated with their ornaments, and covered with glaze, which on the second firing become vitrified. Coarse pottery, however, is not sufficiently valuable to admit of two firings. The glaze is therefore added while the ware is still in the kiln, at a high temperature. For this purpose moist salt is thrown into the kiln, and becoming volatilized and decomposed in the presence of moisture and of hot clay, hydrochloric acid is disengaged, the silica of the ware unites with the soda of the salt, and this, combining with the silicate of the alumina, forms a fusible double alkaline silicate or glaze on the surface of the articles.

The clays used in the Staffordshire potteries are obtained from Devonshire and Dorsetshire, the latter furnishing *brown* and *blue* clays, and the former *black* and *cracking* clays. The black clay contains a little bitumen or coaly matter, which disappears in the kiln and produces a nearly white biscuit. Cracking clay is liable to crack during the first burning, but its white colour renders it valuable for mixing with other clays. Brown clay is liable to the objection of *crazing* or cracking of the glaze, from the unequal expansion between the glaze and the body of the ware. For ordinary purposes blue clay is in great request; but for the finer kinds of earthenware the *China clay*, or *kaolin*, of Cornwall, consisting of felspar in a partially decomposed state, is much employed. It is a white, impalpable powder, containing 60 parts of alumina, and 20 of silica.

The silica used for mixing with the clays is obtained from the flints of the chalk district. The mineral *Pegmatite* contains all the materials for hard porcelain ready mixed.

The preparation of the materials involves a number of processes, and much care and judgment on the part of the manufacturer. The different kinds of clay, such as blue and white, being mixed in the proper proportions, are worked together with water by means of a long wooden blade, called a *blunger* or *plunger*, and the operation is called *blunging* (fig. 302). To assist the blunging, the clay is sometimes passed through a *pug-mill* (fig. 303), consisting of a cast-iron cylinder, lined with knives, and furnished with an upright shaft in the centre, also furnished with a spiral line of knives. These knives act like shears, and cut the clay, as it passes from the top downwards (fig. 304), into small pieces, which are forced out through an opening at the bottom of the cylinder, whence it is removed to a vat for the blunging.

The flints are prepared by calcining in a kiln, quenching in water to increase their brittleness, and reducing them to fragments by means of the stampers, fig. 306. These fragments are reduced to powder in a *flint-pan*, figs. 307, 308, consisting of a circular vat, the bottom of which is formed of felspar, and containing in the centre an upright shaft with four projecting arms or frames, by which motion is given to the *runners*. These are large siliceous stones, called *chert*, and serve to grind the flints to powder by their lower surfaces crushing the flints against the bottom of the vat. In the course of some hours the flints are reduced to powder, which, mixing with the water of the vat, forms a creamy mixture. The flint-powder is considered fit to mix with the clay when a wine pint of it weighs 32 oz., an equal bulk of the diluted clay weighing 24 oz. These two ingredients are mixed by agitation, and passed through sieves of hard-spun silk, arranged on different levels, as shown in fig. 305, so as to allow the mixture to pass from coarser to finer sieves, the straining being assisted by a *jigging* motion given to the sieves. The mixture is now called *slip*, and has next to be brought to the proper degree of thickness required by the potter. For this purpose it is boiled in a *slip-kiln* (fig. 309); it consists of a long brick trough, with flues under it for heating the mixture: it is kept constantly agitated to prevent the heavier flint from settling, and when a sufficient quantity of water has been evaporated, the mixture is taken out and subjected to the process of *wedging*. This consists in cutting up the mass in the slip-kiln into wedges, and dashing them against each other, so as to get rid of air-bubbles, which would otherwise form blisters in the ware. This wedging is carried on at intervals during several months, and during this *ageing* of the paste a fermentation takes place; gases are given off, and the paste improves in texture and in colour. When the paste is about to be used, it is passed through the process of *slapping*, in which a man takes up a mass of 60 or 70 lbs. weight and dashes it down on the bench before him, dividing it frequently by drawing a wire through it and dashing down one fragment upon the other, taking care to preserve the *grain* of the paste, that is, to slap the layers parallel to each other, and not at an angle; for if this were not attended to, the ware would be liable to fall to pieces in the baking.

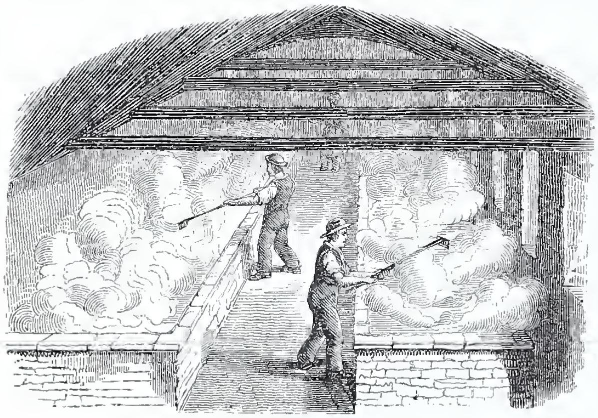
The first process in the manufacture of earthenware vessels is *throwing*. It is performed by means of the *potter's wheel* or *lathe*, fig. 310, which consists of an upright shaft with a disk of wood at the top, and a grooved pulley at the bottom, over which passes a band from a wheel, the revolution of which imparts the required degree of speed to the shaft and its top-board. The paste, as furnished by the slapper, is weighed out into portions of the proper dimensions for the required article, and rolled up into balls; the thrower, seated at his work, as shown in fig. 310, dashes one of these balls upon the centre of the revolving board, and with both hands squeezes up the clay into a conical form, and again forces it down into a mass in order to give it solidity. With one hand, or with the finger and thumb, in the mass he gives the first rude form to the vessel; and then with a piece of horn called a *rib*, which has the profile of the shape of the vessel, he smooths the inner surface, the attendant meanwhile moving the wheel at different rates of speed, according to the direction of the thrower. In order to give the vessels the same height, the thrower has before him a simple gauge, the point of which marks the height of the intended vessel. It is obvious, from the nature of the process, that the thrower can only produce circular vessels, such as basins, tea-cups, &c., the ornaments, handles, &c., to which, being added by an after process. As soon as one vessel is complete, it is cut off at the base by passing under it a fine brass wire, and the thrower proceeds to work another ball. The process of throwing may be further illustrated by means of figs. 311, 312. In order to form the lower part of the vase D, fig. 312, the thrower dashes upon his wheel the lump of clay A, fig. 311. This is worked into the conical mass B; then into the rude cup C, and lastly into D. The portion E, of fig. 312, is represented on the wheel at E, fig. 311. It will be observed that in all the figures on the wheel a spiral grain is given to the clay, which is best adapted to retain the form of the plastic material. There is always a tendency to distortion during the baking, which may be estimated by drawing a vertical line, or two points in the same vertical, upon the soft clay vessel: it will be found after the firing that these two points are no longer in the same vertical; the lower point will have moved more towards the right than the other; a fact so well known to the workmen, that in sticking on handles to vessels, they place them somewhat askew, and the distortion produced by the contraction in firing, restores them to their erect position.

It will be observed that the members D, E, fig. 311, are much thicker than the corresponding parts in fig. 312. They cannot be produced so thin in the operation of throwing, but are reduced by being put into a turning-lathe and worked with cutting-tools just in the same manner as articles in wood, ivory, and metal, are produced by turning. In this way the outer surfaces of cups, &c., acquire that finish and polish, together with rings and other ornaments capable of being produced in this way. By the process known as *engine-turning*, variety is given to the rim, and various kinds of indentations are produced.

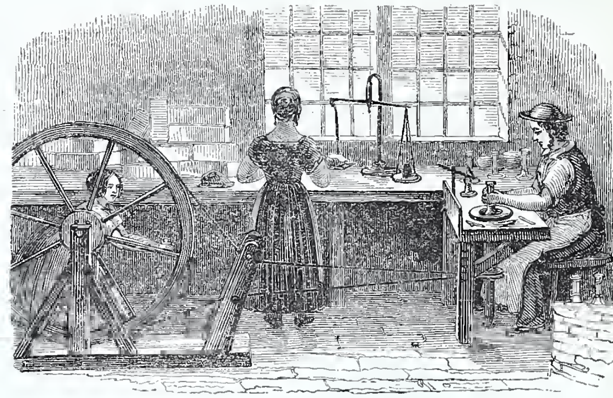
The articles are still in the *green state*, as it is called, and handles, spouts, and other additions are attached to them by means of slip. The paste for the handles is first formed into a long cylinder or other form, by forcing it through a metal tube at a small press, and then cutting it up into lengths and bending them to the required shape. Ornamental handles, &c., may be formed by pressing the paste into plaster of Paris or steel moulds (fig. 316).

The second method of forming articles in earthenware is by *pressing*, which is the same operation on a larger scale as the method just noticed of forming ornaments in plaster moulds. Plates and dishes are made by this method. Deep vessels, such as ewers, vases, &c., are formed in moulds generally made in four parts, fitting accurately together. The paste is rolled out much in the same way as in preparing the crust of a pie; and each section of the mould being carefully lined with it, the edges are trimmed and moistened with slip, and the parts of the mould are carefully brought together and secured by a strap. The presser then passes his finger up each joint so as to form a channel into which a thin roll of clay is inserted. This is worked in, first by the finger and thumb, and then smoothed with moist leather. Fig. 319 shows the presser at work, while figs. 313, 314, and 317 show the moulds or portions thereof. The mould is placed in a warm room, and when sufficiently dry is taken to pieces, and the article is removed to be *fettled* or trimmed with proper tools, to get rid of the appearance of seams and to remove superfluous portions of clay. The article is then cleaned and polished with a moist sponge, the handles and other appendages are added, and lastly it is polished with horn, and is set aside to dry previous to baking.

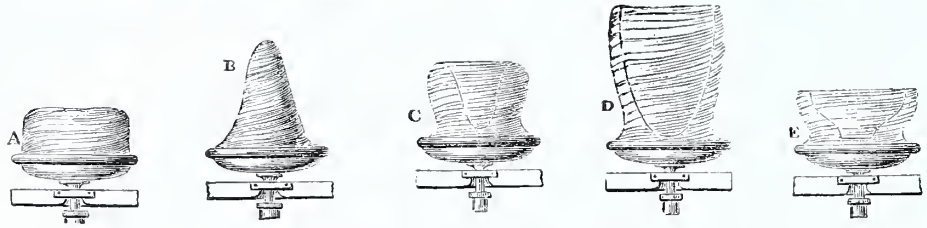
There is yet another method of forming articles in earthenware, namely, by *casting*. The paste, being mixed with water, is



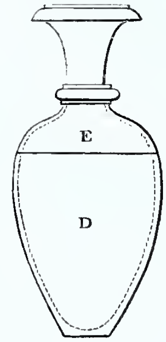
309. SLIP-KILNS.



310. THROWING.

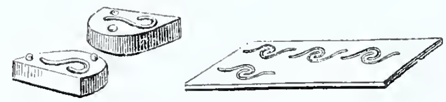


311. PROGRESSIVE STAGES OF THROWING.



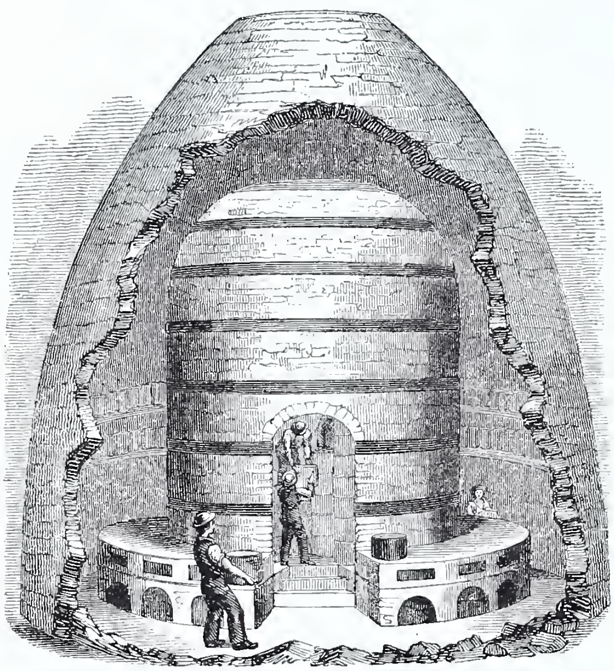
312. VASE.

313. MOULD.

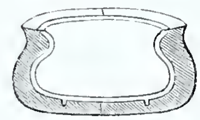


31 MOULD FOR HANDLES.

314. MOULD.



315. BISCUIT KILN.

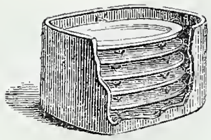


317. MOULD.

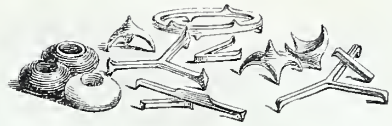
318. UNGLAZED POTTERY FROM TUNIS.

319. HOLLOW WARE PRESSING.

320. PRINTING STONE WARE.

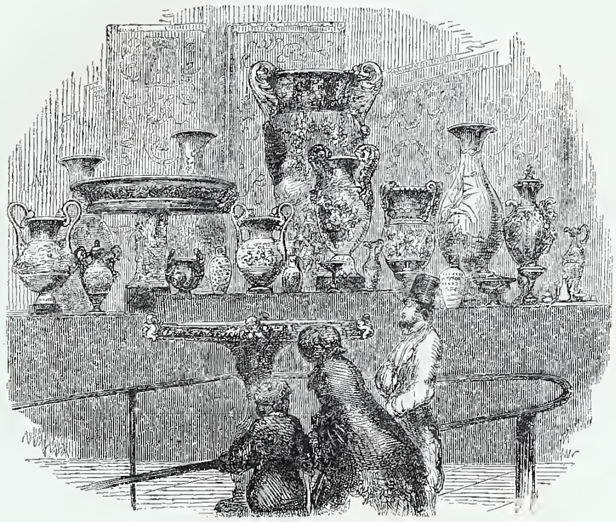


321. SEGGAR.



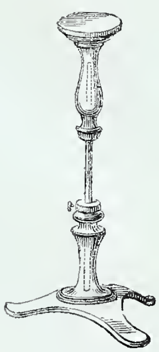
322. WATCHES, COCKSPURS, TRIANGLES, AND STILTS

323. PAINTING PORCELAIN.



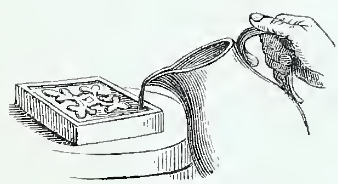
324. SÈVRES PO RCELAIN.

325. BURNISHING.

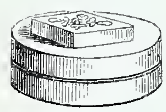


326. WHIRLER.

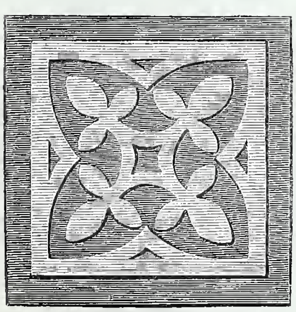
327. PRESSING AND SCRAPING TILES.



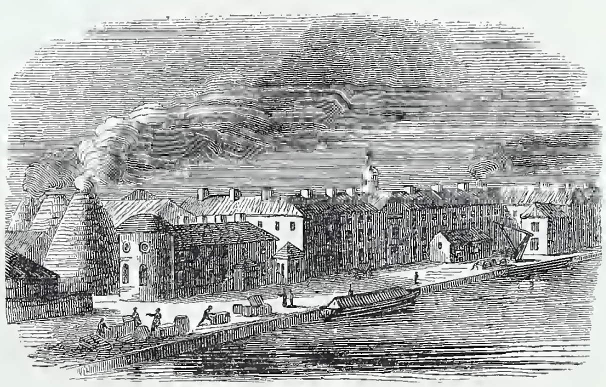
328. FILLING.



329. WHIRLER.



330. ENCAUSTIC TILE.
(*Yellow on blue ground.*)



331. WEDGWOOD'S FACTORY AT ETRURIA, IN STAFFORDSHIRE.

332. ENCAUSTIC TILE.
(*White on black ground.*)

poured into a mould, the plaster of which quickly absorbs a sufficient portion of the water of the mixture, to leave on its walls a thin lining of the paste thus suddenly removed from solution. The fluid portion in the mould is then quickly poured off; and when the delicate lining is sufficiently dry, the mould is again filled with the fluid mixture, and again quickly emptied. The mould is then placed in a stove, and when dry it is taken to pieces, and the object removed. Statuettes and other articles are formed in this way.

The processes above described apply to porcelain paste as well as to pottery; so that we may now pass on to the process of *firing*. The articles in the green state are kept in a heated room until they have parted with much of their moisture. When sufficiently dry, they are placed in coarse strong vessels of marl, called *seggars*, for the purpose of protecting them from the direct action of the fire and the products of combustion. Most of the seggars are oval in shape (fig. 321), but those used for plates are cylindrical. The articles are prevented from touching each other by placing between them sand or powdered flint, and in some cases rings of earthenware are placed in saucers, cups, &c., to preserve their shape. As the seggars are filled, they are conveyed to the kiln (fig. 315), and are piled up so that the flat bottom of one seggar may serve as a cover to the one above it: a roll of clay is placed on the rim of each seggar, for the one above it to stand on. Each pile of seggars is called a *bung*. About 30,000 pieces of ware may be included in one baking.

The kiln (fig. 315) is surrounded by an outer cone or *hovel* of brickwork, a portion of which is removed in the engraving to show the interior arrangements. The kiln itself is a domed cylinder of brickwork bound with iron bands, and with a hole in the top immediately under the chimney of the hovel to allow the smoke to escape. The kiln is surrounded by a number of fires and flues, arranged so as to produce a high and equable temperature within. The use of the hovel is to protect the kiln from the weather, and to furnish a chimney to the kiln. It is furnished with shelves inside, on which newly-made seggars are arranged for drying previous to baking. When the kiln is filled, the doorway is bricked up, the fires are lighted, and in the course of three or four hours flame is seen to ascend through the cylinder into the chimney of the hovel. After about ten or twelve hours, the fireman takes out his first *watch* to see how the baking goes on. *Watches*, or *trial-pieces*, are rings of fire-clay which assume different shades of colour at different temperatures. A number of these are placed in a seggar opposite a hole in the cylinder, and the fireman, removing the clay stopple from this hole, inserts a long iron rod, and withdraws a watch. When it is cold, he is able to judge by its colour of the heat of the kiln, and to regulate it accordingly. During the next twenty or thirty hours he frequently draws out a watch, and when he deems the baking to have been sufficient, the fires are allowed to go out, and the kiln is left to cool during twenty-four or thirty hours. About fourteen tons of coal may be consumed in one baking.

The ware is now in the state called *biscuit;* not because it has been twice cooked or baked, but because it resembles the dry and rough surface of well-baked ship bread. Some articles, such as wine-coolers, butter-coolers, and water-bottles, are finished in the state of biscuit. It is in the condition of the unglazed pottery-ware of Tunis (fig. 318). Water contained in these vessels, slowly oozes through the ware, and forms a dew on the outside, the evaporation of which carries off so much heat as to lower the temperature of the remaining liquid many degrees below that of the air.

When the ware is removed from the seggars, it is carefully examined. White and cream-coloured wares require only a coating of glaze to fit them for the market. Patterns are added in the state of biscuit by a transfer process now to be described. For example, the blue of the common dinner-service is produced by means of oxide of cobalt, ground flints and sulphate of baryta, fused or fritted together, reduced to powder, mixed with a flux of ground flint and thick glass powder, and then mixed with boiled linseed oil: this forms a viscid kind of printers' or engravers' ink, and with this the lines of the pattern engraved upon copper plates are filled in. A wet sheet of thin yellow unsized paper is now placed upon the copper plate, and with it passed through a cylinder press: the paper receives the impression from the plate, and a little girl called the *cutter* cuts the pattern into its separate parts, rejecting the white unprinted portions, and hands them to a woman called the *transferrer* (fig. 320), who places the several sections of the pattern, with the ink part downwards, in their proper places, upon an article in biscuit-ware, and by rubbing the paper with a roll of flannel, transfers the ink from the paper to the porous biscuit. On placing the articles in water, the paper separates, leaving the pattern on the ware. The article is next dipped into glaze, which, when dry, gives it a white porous chalky appearance, completely concealing the pattern; but on passing the article a second time through the kiln, the white powder fuses into a transparent glass, through which the pattern is visible; while at the same time, it deprives the biscuit of its porous character, improves its appearance, and renders it fit for use.

Glazes usually contain flint and an alkali, the common ingredients of glass, and often a portion of lead, tin, or borax, to render them more fusible. They may be *transparent*, *opaque*, or *coloured*. If the paste be white, or of a tint pleasant to the eye, a transparent glaze will improve its appearance. A clay possessing good plastic qualities, but a bad colour, may be dipped into a slip made of a superior kind of clay: it may be veneered on the inside with a pure white paste, and ornamented on the outside with variously coloured pastes: in such a case, a transparent glaze would be proper. When the glazes are made opaque by means of oxide of tin, &c., they become true enamels, and effectually conceal the body of the ware which they cover. Colour is given to glazes by the addition of various metallic oxides.

The glazes are applied by reducing them to fine powder, mixing them up with water, and plunging the biscuit-ware into the mixture: if this be skilfully done, the porous ware will be completely covered with glaze in fine powder, except at the points where the article was held, and these are afterwards coated by a camel's hair brush dipped in the powder. The glaze thus applied is vitrified in the *glaze* or *gloss* oven. In arranging the articles in the seggars, they are prevented from touching each other by being made to rest on supports of various forms, and known as *cockspurs*, *triangles*, *stilts*, &c. (fig. 322). The method of arranging flat pieces in the seggar is shown in fig. 321. The seggars are piled up in the glaze-kiln as in the biscuit-kiln; the temperature is raised sufficiently to fuse the glaze, an effect which is judged of by covering watches with glaze (fig. 322), which, being drawn out from time to time, serve to guide the workman.

The ornamentation of porcelain belongs rather to the fine arts than the useful arts. Porcelain may indeed aspire to the dignity of having created schools of art, which have had their rise, their prosperous days, and their fall, their great masters, and their imitators, their admirers, in whom the love of china-ware amounts to a passion, who do not even now hesitate to give 200 guineas for a single plate, a similar sum for a cup and saucer, and 1000 pounds for a single vase, provided they are satisfied that such articles represent the best days of Sèvres or of Dresden, of Chelsea or of Capo di Monti, &c. The famous *Majolica*, or enamelled ware of Italy, was dignified by no less an artist than Raphael furnishing designs for it; and his successors, catching the tone and manner of the great master, produced those numerous works which still dazzle us with the splendour of their colouring; while some of them, known as *amatorii*, are adorned with the portraits and names of ladies in the costume of at least three centuries ago. Then again, there is the curious ware of Palissy, the hero of potters, who, when persecuted for his Protestant opinions, declared that no power on earth should compel him to worship the images which he had made with his own hands. One of his favourite subjects is a basin or dish,

representing the bottom of the sea, covered with fishes, shells, sea-weeds, and pebbles. It is not our business to inquire into the taste which covers with beautiful pictures such common articles as dinner-plates and cups and saucers, which we soil with our food, and place in various positions on the table, all more or less unfitted for viewing a picture; nor is it our business to show how intensely difficult is this art of enamel painting: for the artist has to grope his way, as it were, in the dark, painting with certain metallic oxides ground up in oil, which do not represent the colours intended to be produced until they have been passed through the fire; then there are the dangers and difficulties of firing, whereby the piece may be cracked or crazed, or the surface scaled, or the piece may require to be retouched and passed again and again through the fire; and the only advantage that this difficult art presents over oil-painting is its permanence, for should the article escape fracture, it is otherwise indestructible. There is, however, no doubt that the taste for china ware greatly improved our earthenware. Under the influence of such a man as Wedgwood (whose factory at Etruria, in Staffordshire, is represented at fig. 331), and with the assistance of such a designer as the great sculptor Flaxman, a variety of beautiful wares for common use were issued at a cheap rate, the effect of which had a beneficial influence on the public taste. Wedgwood began life at the age of eleven as a thrower, but an attack of small-pox compelled him to give up this employment. The attack left him with a lame leg, which afterwards rendered amputation necessary. For some years his attempts to settle in life were not successful; but he appears on several occasions to have gratified his love of the beautiful by the manufacture of ornamental pottery. In 1759, he established a small factory of his own at Burslem, where he succeeded in making a white stone-ware, and afterwards a cream-coloured ware, some specimens of which he presented to Queen Charlotte, who was so pleased with it that she ordered a complete service, which obtained further marks of the royal favour: Wedgwood was named "The Queen's potter," and his ware, "by command," *The Queen's ware*. He also invented a *terra cotta*, which could be made to resemble porphyry, granite, &c.; also *basalts*, or black ware, which would strike sparks with iron; white porcelain biscuit, with properties similar to the basalt; *bamboo* or cane-coloured biscuit; *jasper*, a white biscuit of great delicacy and beauty, fit for cameos, portraits, &c.; and a porcelain biscuit, used for chemists' mortars, &c. He also succeeded in giving to hard pottery the vivid colours and brilliant glazing which had been thought peculiar to porcelain; and with a true feeling for his art, he introduced a higher class of artists than had been hitherto accustomed to work in the potteries. The extension of Wedgwood's works led to the formation of a new village, which was named Etruria, from the resemblance of the clay dug there to the ancient Etrurian earth, and also, probably, to note the success with which he imitated the ancient Etruscan ware.

Painting on porcelain (fig. 323) does not greatly differ from other applications of the palette, except in the dingy nature of the pigments when first applied, and the brilliant creaminess of surface after the firing. The gold employed in gilding porcelain is first dissolved in *aqua regia;* the acid is then driven off by heat, and the residue, mixed with borax and gum-water, is applied to the wares with a hair pencil. When an article has to be ornamented with a circular line, it is placed on a *whirler* (fig. 326); and on holding a pencil against the article and turning round the upper part of the instrument, a circle is easily and truly described. When the articles have been baked, the gold appears of a dingy hue; but the beautiful lustre of the metal is brought out by burnishing with agate and blood-stone (fig. 325).

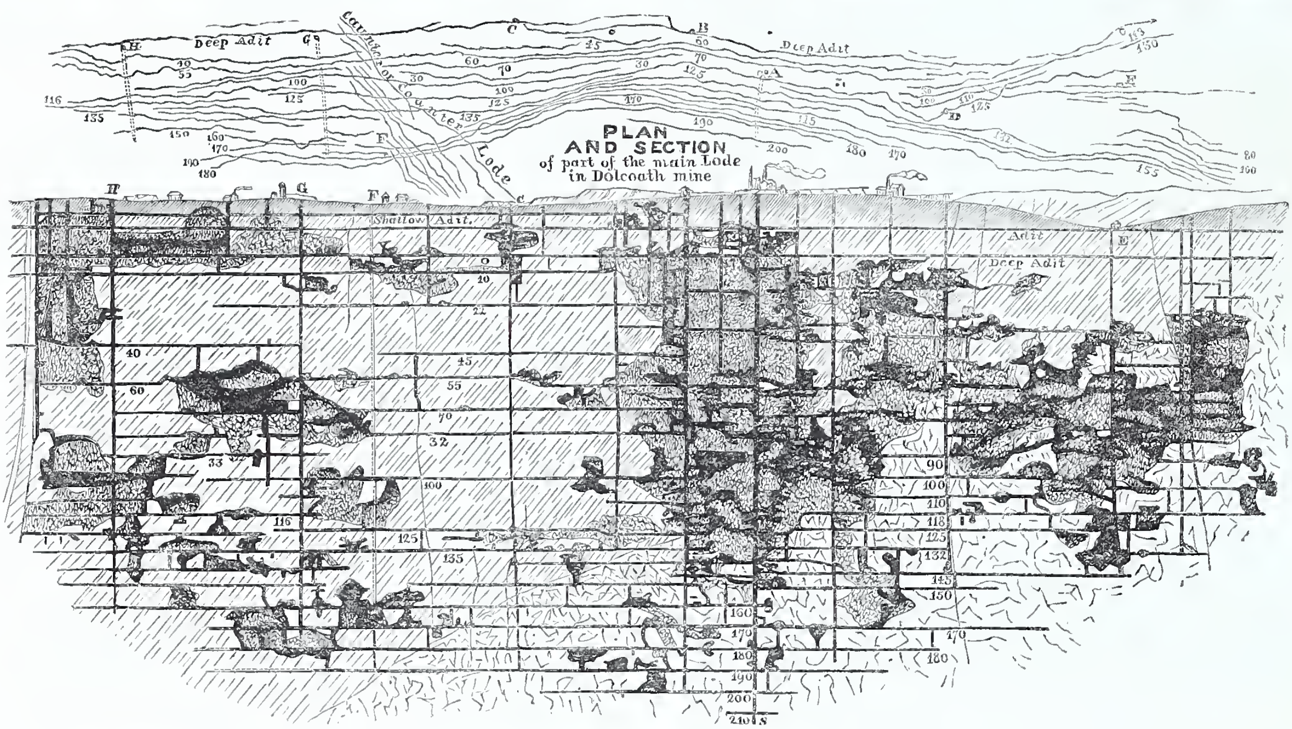
The manufacture of encaustic tiles has of late years risen into importance, as one of the results of improved taste in church architecture and decoration. These tiles are an example of veneering an inferior clay with a superior, as already referred to. The red clay is slapped into a block, of a square section, and the tile-maker cuts from this a square slab by passing a wire through it, and upon this a facing of finer clay, coloured so as to form the ground of the tile, is applied: the tile is then turned over, and a facing is applied to the bottom to prevent warping: the tile is then covered with a piece of felt, put into a press (fig. 327), and a plaster-of-Paris slab, containing the pattern in relief, is brought down upon the face of the tile, and impresses in the soft clay or ground of the tile the design which is afterwards to be filled in with another colour. When the tile is removed from the press, the name of the maker is stamped on the back, together with a number of holes, to make the mortar adhere when the pavement is laid down. The device is then filled in by pouring over the tile a quantity of coloured slip (fig. 328), so as completely to conceal the surface: this is left for twenty-four hours to become hard, when the pile is placed on a small whirler, fig. 329; and a portion of the surface being scraped away, the pattern and the ground appear. The tile is lastly made smooth, and is polished with a knife, small defects are corrected, the edges are squared and rounded a little with sand-paper, and the tile, after having been dried in a hot room, is ready for firing.

Our export trade in earthenware is of some importance. In the year 1856, the number of pieces of ware exported was 94,551,260, of the declared value of 1,331,106*l.* sterling.

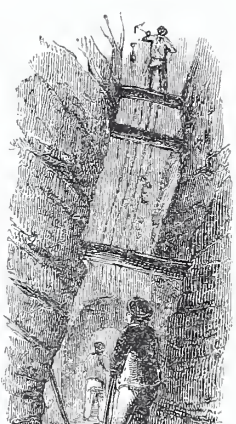
333. A WINZE.

334. BURRA BURRA MINE, SOUTH AUSTRALIA.

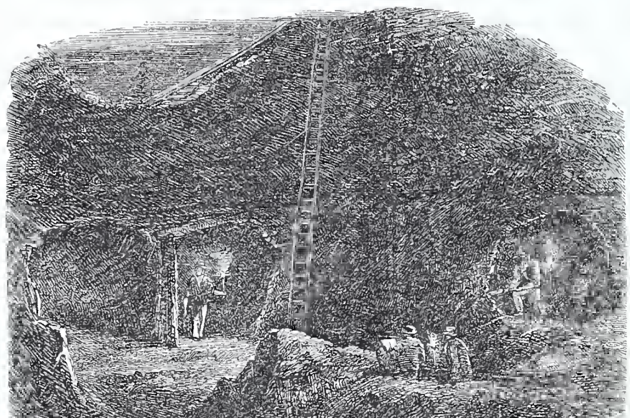
335. WHIM SHAFT.



336.

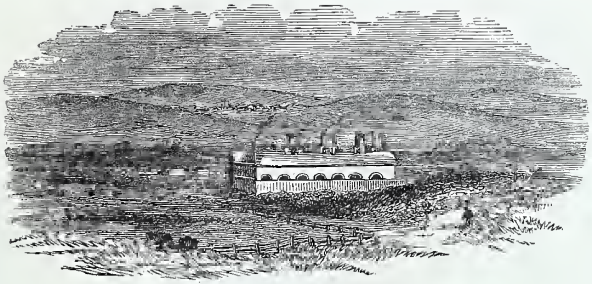


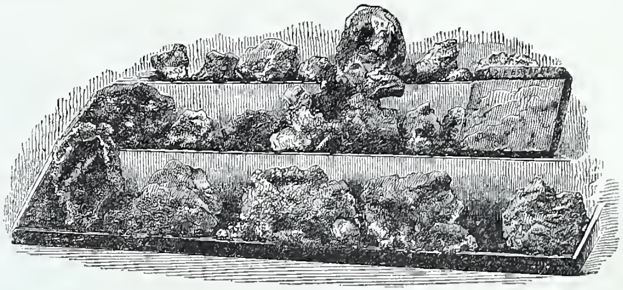
337. TIMBER SUPPORTS.



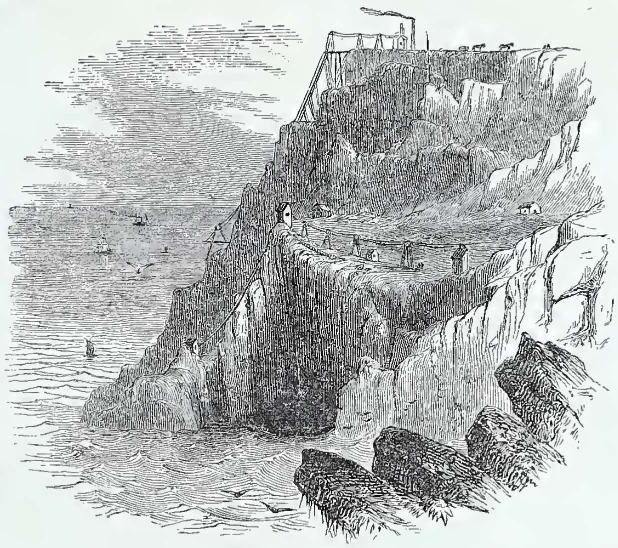
338. METHOD OF WORKING THE LODE AT BURRA BURRA.

339. SETTING A SHOT.

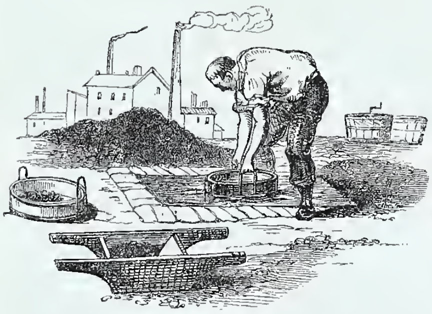

340. BURRA BURRA SMELTING HOUSES.

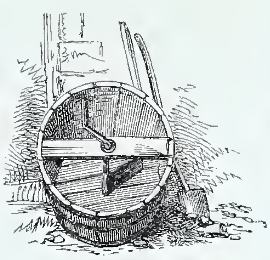

341. COPPER ORE.


342. A PLATT.


343. EXTERIOR WORKS AT BOTALLACK MINE.

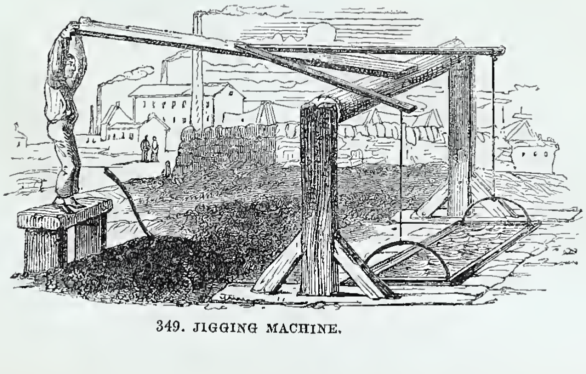

344. BUDDLING.

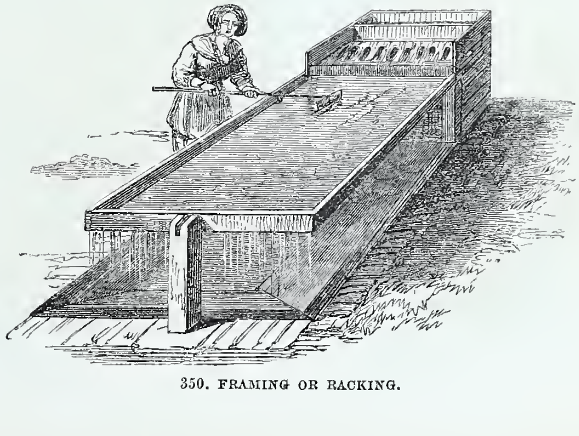

345. JIGGING.


346. THE KIEVE.


347. TOSSING OR TOZING.


348. TYING.


349. JIGGING MACHINE.


350. FRAMING OR RACKING.

XXII.—MINING OPERATIONS.

Nothing in the British islands excites so much surprise in an intelligent foreigner as the wonderful diversity of mineral wealth which it has pleased Almighty Wisdom to bestow upon this favoured land. We have rich stores of iron ore and abundance of fuel for reducing it, building-stones for constructing the furnaces, and fluxes for working the ores more easily. Iron and coal are so extensively distributed that it would occupy too much of our space to point out their localities. In Cornwall tin ore is abundant, copper in Wales, lead in Derbyshire and in the valleys of the Tyne, the Wear, and the Tees: in short, we have all the materials for constructing machines at the lowest possible cost, and abundance of fuel for working the steam-engine which sets them all in motion.

Our mineral riches are brought to the surface by means which vary with the mode in which they are deposited. In some cases the minerals form regular strata, and alternate with beds of rock of considerable extent, as in the strata of coal and iron ore of South Wales and Staffordshire, and the coal in the Newcastle and Durham districts: in other cases metallic ores may occupy cracks or fissures in the rocks, forming what are called *veins* or *lodes*. When these cracks are filled up with non-metallic substances, they are called *dykes;* but when they accompany veins of ore, and are at right angles thereto, they are called *cross-courses*. The metalliferous veins are not filled with metal in its pure or native state, but in the state of *ore*, that is, united with sulphur, oxygen, carbonic acid, and associated with salts of lime, baryta, quartz, and argillaceous matter.

The object of mining is to pursue one or more of these veins through the rocks which are met with in its downward descent, and to raise the ore to the surface. Supposing that by previous borings and other trials the position and direction of the vein is known, a pit or shaft is sunk to the depth of about sixty feet, when the men begin to work in a horizontal direction, and to cut or *drive* a horizontal gallery or level into the lode. This is usually done by two sets of miners, working in opposite directions, and the rubbish and the ore, if any, are raised by a common windlass. As soon as the two sets of miners have driven a level about one hundred yards, they cannot proceed farther for want of air; but in the mean time two other sets of men have been sinking from the surface two other vertical shafts to meet them, and in this way the work proceeds, the first level or gallery being driven to any required extent by sinking vertical shafts into it. While the horizontal gallery is being driven, the first shaft, called the *engine-shaft,* is sunk deeper, and at a second depth of sixty feet a second horizontal gallery or level is driven in the same direction as the first, and the vertical shafts are all sunk down to meet it. In this way galleries are formed at different depths, so long as the lode continues to be profitable. In the mean time the engine-shaft is sunk deeper than the lowest level, in order to keep the working shafts free from water, which rises in the mine from springs, or drains into it from the surrounding strata. Each successive level is also separately drained, in order that the lower workings may be kept as free from water as possible. The arrangement, such as we have described it, divides the rock into solid right-angled masses, each three hundred feet in length and sixty feet in depth. These masses are again subdivided by small vertical shafts, or *winzes* (fig. 333), into parts, called *pitches*. The principal gallery or tunnel by which the mine is drained is called the *adit*, or *adit-level*. To drive this from one point to another through a great extent of country, particularly where the work is commenced at both extremities, requires much skill. Attention is also required that the water, pumped up from the various channels, may not find its way back again to the workings. Some idea may be formed of the extent of the drainage required in extensive mines, from the fact that the various branches of the principal level in Cornwall, called the "Great Adit," through which the waters of the different mines in Gwenap and near Redruth are discharged, measure nearly thirty miles. The adit opens at the side of a hill at such an elevation as to discharge its waters into some stream or river, which flows into the sea, and in some cases the adit discharges into the sea itself.

The workings on different lodes are connected by *cross-cuts*, so that the ores may be brought to the principal shaft of the mine with the greatest ease. The work underground depends chiefly on the size of the vein and the value of the ore. When the lode is only a few feet wide, one gallery is sufficient; and as it is only necessary to leave a passage to extract the ore, the levels are here narrow and confined. But where the lode is broader, the open spaces are larger. When large masses of ore have to be taken out, pillars are left to support the *roof*, as one side of the wall or portion of rock which incloses the vein is called; the other wall being called the *floor*. But as these pillars contain valuable ore, the roof is often supported by *timbering* (fig. 337). The ore is extracted from the rock by means of gunpowder, for which purpose a cylindrical hole is bored in the rock, a charge of powder is introduced, a fuse inserted, the hole stopped or *tamped*, and after setting fire to the fuse the men retire till the explosion is over. Fig. 339 shows the men at work setting a fuze, or *shot*, as it is called.

When the ore has been detached, it is conveyed to the bottom of the principal shaft in wagons or *corves*, moving on tram-roads or rail-roads. The ores are lifted by machinery from the bottom of the shaft to the surface by a *whim*, worked by steam-power. In some of the Cornish mines it is not uncommon to sink two shafts near together; one, called the *engine-shaft*, being used for drainage, and a smaller one for drawing the stuff. The shafts are commonly four-sided; that intended for the extraction of the ore is called the *whim-shaft*. Fig. 335 represents what is called a *platt*, which is a sort of cavity at the extremity of a level, near the whim-shaft, for the purpose of collecting supplies of ore for filling the *kibbles* by which it is raised to the surface. The men are setting a *shot* for blasting, in order to enlarge the platt. A small kibble is shown hanging over a small *sump* or cavity at the bottom of the shaft for receiving the drainage water. Fig. 342 shows a platt complete, with the kibble hanging in the whim-shaft, which is boarded off from the platt, to prevent accidents. The method of working the lode at Burra Burra Mine (fig. 334) is represented at fig. 338. In this very successful mine the copper ore, instead of forming a vein, constitutes an enormous nodulous mineral deposit in clay. Some of the nodules are of large size; and there were specimens in the Great Exhibition (see fig. 341) measuring two and a half feet by two feet superficial, with a thickness of six inches.

Fig. 336 represents a plan and section of part of the main lode in Dolcoath Mine, Cornwall. In the upper part of the figure or plan, the ground is supposed to be transparent, to show the underground levels. The numbers attached to the lines which represent the levels give the respective depths below the adit; so that if perpendicular lines were let fall from this level upon such lines, they would cut them at the various depths marked in fathoms. In the lower figure or section the lines of levels and letters of reference correspond with the plan. In this section those portions have been left blank which have been cut for galleries in the levels, the shafts, and where *bunches* or accumulations of ore occur; while those parts in which the rubbish of the workings has been thrown back, and arranged so that the galleries or levels and the shafts should pass freely through them, are represented as being composed of broken fragments. The

killas or slate is white, and the granite dotted. The main lode cuts into granite in its eastern prolongation, and a tabular mass of granite is cut by the lode and apparently separated from the rock. Bunches of ore have occurred very irregularly, and the spaces occupied by them have been filled up with rubbish from other parts of the mine. Levels on the east have been driven into the granite in search of ore, but they have been abandoned; the sump or lowest part of the engine-shaft marked *s* is at the depth of 210 fathoms. At the time when this plan was made, the ores were drawn up by four shafts by three steam-whims, indicated on the surface: the position and number of the shafts, however, varies with the state of the mine; and as every shaft has its name, and every level is known by its depth, a mine resembles a town in which the streets are known by names and the houses by numbers.

When mines are situated near the coast, they often present rugged and sublime features. Near the Land's End, in Cornwall, the direction of the veins and the distribution of the ores direct many of the mining operations beneath the bed of the Atlantic. In the Botallack Mine, fig. 343, the miners followed the ore upwards into the sea; but as the openings were small and the rock hard, the water was excluded by plugging. During rough weather the sounds which penetrate the mine are described as being appalling.

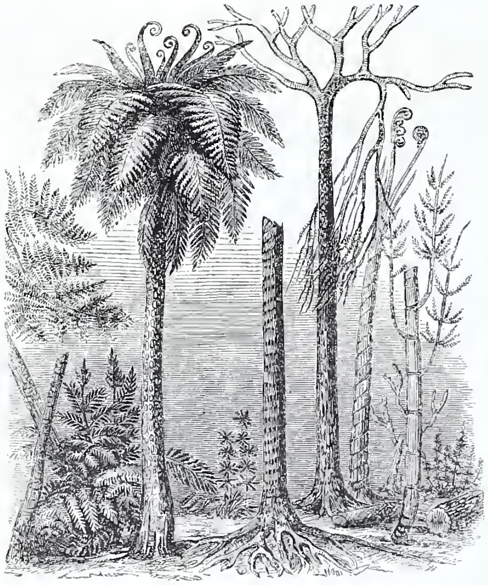
When the ore has been raised to the surface, it undergoes various operations previous to smelting. Tin ores are usually so far purified as to render the smelting a simple process. Copper ores, on the contrary, depend more on chemical than mechanical treatment for their purification; so that little is done except to separate stony matters, when the ore is sent to Swansea, where coal is abundant, to undergo the complicated series of processes by which it is converted into metallic copper.

When the tin ores are raised, the first operation is to break them in pieces and to reject such portions as are too poor to repay the cost of *dressing*. The ore is then sent to the *stamping-mill*, which consists of a number of upright wooden beams or *stampers*, shod with iron: these are placed in a wooden frame, and lifted about ten inches by the cogs of a horizontal axle, the rotation of which thus gives a stamping motion to the upright wooden beams. The ore is placed on an inclined plane near the bottom of the stampers; and as these are lifted up, a portion of it slides beneath them, and is crushed by their fall. Water being let in, carries the crushed ore into pits, in the first of which the rough parts lodge, as well as the heavier portion of the powdered ore, called the *slime*, the rough ore when dressed being called the *crop*. The remainder, with the lighter slime, is retained in the second pit, and this when dressed is called the *leavings*. The dressing now comprises a number of operations, all of which depend on the fact that the metallic portion which is to be preserved is much heavier than the stony and earthy matters which are to be got rid of.

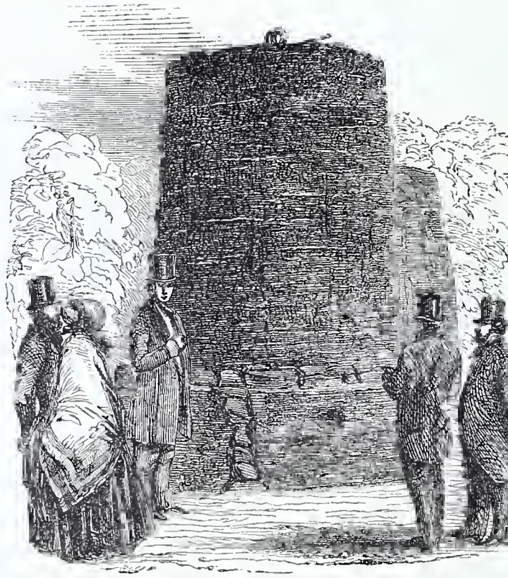
The first operation on the crop is called *buddling*. The buddle (fig. 344) is a wooden case fixed in the ground, one end being elevated: on the rim of the higher end is a board called the *jagging-board*, extending from side to side, and more inclined than the buddle. The operator spreads the ore on the jagging-board, cuts small furrows in it with the shovel, and letting in a current of water from the head of the buddle, the ore is carried into the case, where the finer and richer portions subside near the head, while the rougher and lighter portions are carried towards the lower part. When the buddle is full, it is divided into three or four parts, called *heads*, *first* and *second middle-heads*, and *tails*, the last being the poorest. These are again separately buddled. The heads are then *tossed* or *tozed* in a *kieve* (fig. 346) or large tub, about one-third filled with water, which is rapidly stirred by means of the stirrer shown in the figure, while a second workman gradually adds the ore with a shovel (fig. 347). When the kieve is nearly full, the stirring is stopped, and the kieve is struck with a hammer so as to assist the ore in arranging itself into strata according to their density; the ore in the lowest part of the kieve being generally fit for smelting, while for the other portions the operations are repeated.

The first and second middle-heads are treated in a somewhat similar manner, after which they and the other ores which have been thus far treated are roasted, in order to get rid of ores of copper, iron, or zinc, and when removed from the furnace the ore is sifted, again tossed and buddled, and is then ready for the smelter. Some kinds of ore after roasting require *tying:* the *tye* (fig. 348) is a long, narrow, inclined furrow, through which passes a stream of water, and the ore being placed at the head is agitated with a broom, so that the rough and lighter particles are carried to the lower part, while the ore at the head is fit for the smelting-house. The remainder goes through the operation of jigging (fig. 345), which is performed by plunging a copper-bottomed sieve, containing two or three shovelfuls of ore, into water, and working it about in such a way that the different parts may easily arrange themselves in the order of their respective densities; the lighter portions which come to the top are scraped off, a fresh supply of ore is thrown in and jigged, until at length the weight of the richer portions at the bottom of the sieve is too great for the operation to be continued. It is then removed for the smelting-house. In this operation the *jigging-machine* (fig. 349) is sometimes used: its construction will be understood by referring to the figure.

The poorer portions of the ore, which have been rejected in previous operations, undergo various forms of treatment, known as *trunking*, *framing*, or *racking*, but not differing in principle from the former. In framing or racking, fig. 350, the frame is a flat table with a rim round it: it is suspended on pivots in an inclined position, but is fastened by a kind of latch: at the upper end is a jagging-board similar to that of the buddle, and connected with a frame by a movable sloping piece of wood to prevent the ore from falling between the board and the frame: below the frame are two boxes, which, being placed end to end, extend its whole length; while, at the lower end of the floor, a space of two or three inches allows the water to escape. The woman spreads on the jagging-board a portion of slime, and, with a small toothless rake, makes small furrows in it; and the stream of water which is now let in, carries the ore from the board to the frame: the richest part rests at and near the head; the poorer portions move lower down, while the impurities are carried off by the water and escape by the bottom. When enough has been collected, the latch is lifted, and the frame being turned on the pivots, the ore is swept into the boxes beneath: the best into the upper, and the inferior ore into the lower box.

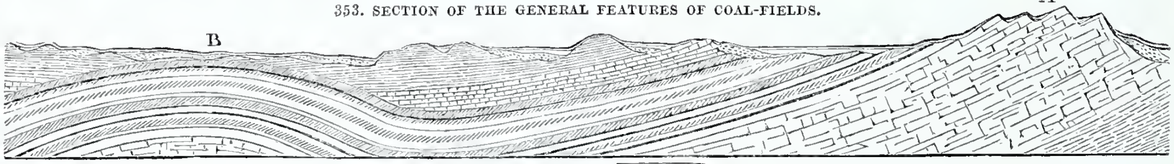


351. PLANTS FORMING COAL.—(*Restored*).



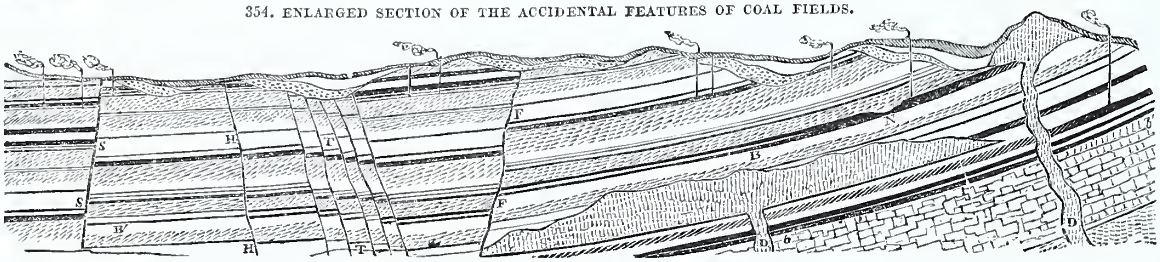
352. IMMENSE BLOCK OF COAL.

353. SECTION OF THE GENERAL FEATURES OF COAL-FIELDS.



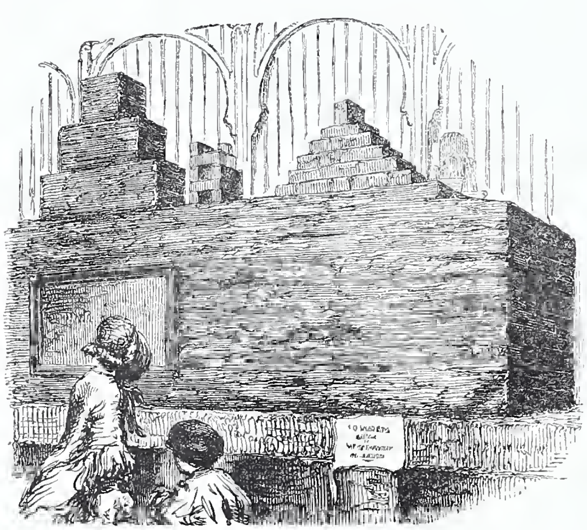
Diluvium (or gravel), alluvium, and mould.
Carboniferous shales, or slaty clays.
———— grits, or coarse sandstones.
Seams of Coal.
New Red Sandstone, and red or variegated marls.
Magnesian Limestone.
Mountain, or Carboniferous, Limestone.
Old, or Lower Red Sandstone.

354. ENLARGED SECTION OF THE ACCIDENTAL FEATURES OF COAL FIELDS.



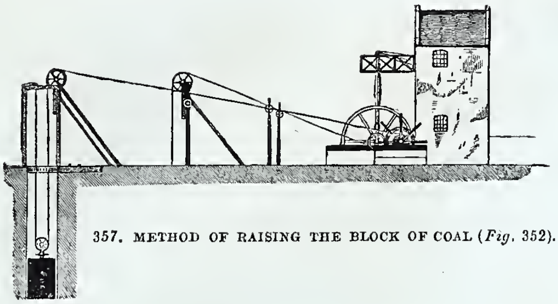
Basalt, and other igneous rocks.
Anthracite, or natural coke.

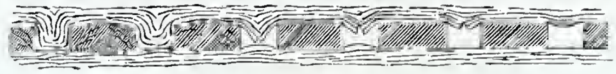
D D, Whin Dykes. F F, S S, Faults, or Slip Dykes. T T, Troubles. H Hitch, or Step. *b* and B B′, Bands. N, Nip, or Baulk.

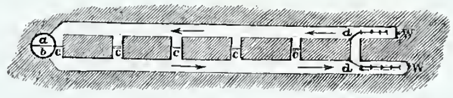


355. BLOCK OF STAVELEY COAL.

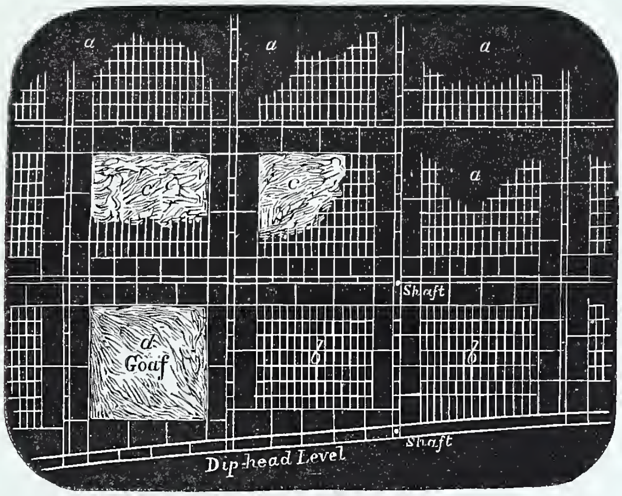
356. FRACTURE OF COAL.


357. METHOD OF RAISING THE BLOCK OF COAL (*Fig.* 352).

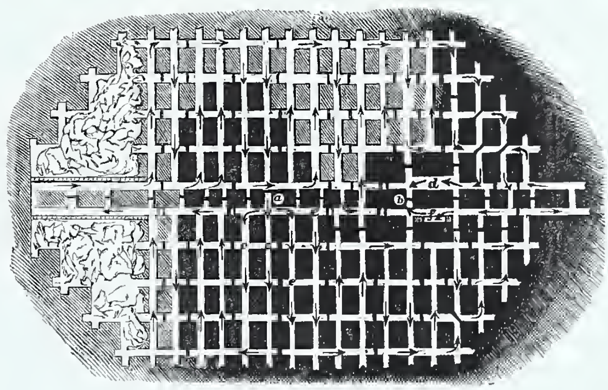

358. A CREEP.



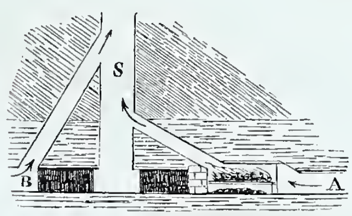
359. VENTILATION OF BORDS.



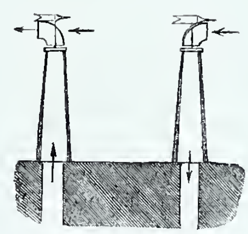
360. PLAN OF COAL-MINE.

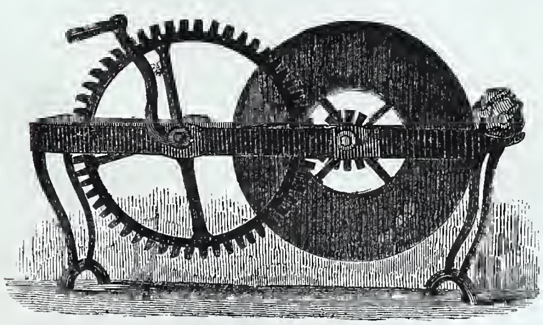


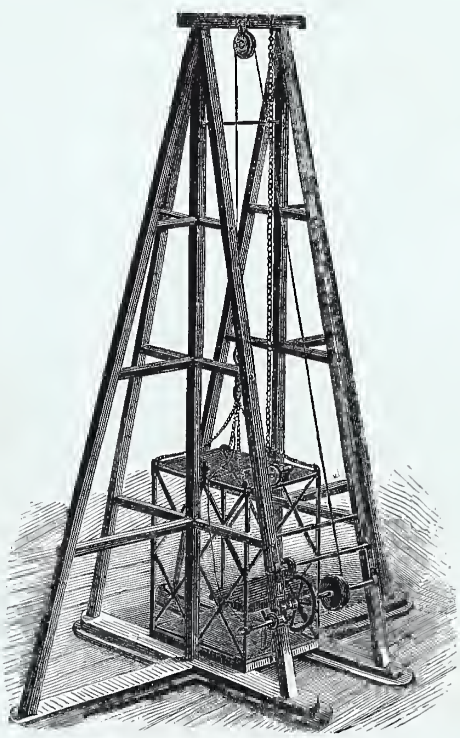
361. VENTILATION OF A COAL-MINE.

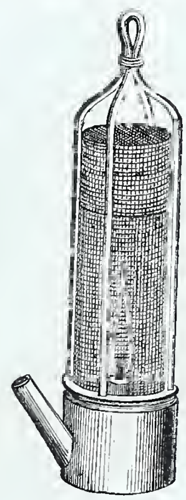


362. DUMB FURNACE.


363. VENTILATING SHAFTS.


364. THE STEEL MILL.


365. FOURDRINIER'S MINERS' APPARATUS.


366. THE DAVY.

XXIII.—COAL.

The vast deposits of coal in Great Britain form one of the sources of her commercial greatness. Coal is superior to every other description of fuel in the wide range of its usefulness. We use it for cooking our food, and for warming and ventilating our rooms; we light our streets and our houses by means of the gas which we distil from it; we use it for reducing ores to the metallic state, and for putting in motion the locomotive, the steam-boat, and the stationary engine, which sets to work innumerable forms of automatic machines. Our supply of this valuable fuel is as abundant and extensive as it is conveniently deposited for distribution. Had our supply been placed in the midst of high mountains, far from the convenience of water-carriage, our rich stores of fuel would have lost much of their value; but as it is, coals are found in or near rich valleys and low plains near the seas and large rivers, well adapted for home consumption in the busy manufacturing towns placed on their banks, and for distribution by water-carriage or by railway.

The examination of a lump of coal renders it evident in most cases that it was formed by the action of certain chemical forces on wood or other vegetable matter. The most rudimentary form of coal is *peat*. In situations where clay is spread over gravel, and water is prevented from escaping, muddy pools are formed, round the borders of which aquatic plants flourish, and gradually creep in towards the deep centre. Mud having accumulated round their roots and stalks, a spongy mass is formed, adapted to the growth of moss, which, together with the spears of the *Sphagnum*, now thrives: this absorbs much water, and continues to shoot out new plants above, while the old ones are decaying and becoming compressed into a solid mass below. Thus the water is replaced by vegetable matter, and the marsh is filled up, while the central or moister portion, growing more rapidly, gradually rises above the edges until the surface has attained such an elevation as to discharge the surface-water and to flood the adjacent country. In this way peat bogs are formed and extend their dimensions, one generation of vegetable matter flourishing upon the ruins of its predecessor. In other cases trees and plants may be drifted from a distance and accumulated in particular localities, as in the *deltas* of the Mississippi and other large rivers; and under the action of an elevated temperature and other chemical forces, they form irregular deposits, which impregnate the surrounding strata. In this way bitumens and fossil resins appear to have been formed, in a manner similar to the deposits of true coal. There is also a kind of coal of a brown colour, known as *lignite* or *brown coal*, which usually retains a woody lamellar structure; but the most highly prized variety of coal is the *bituminous* or *caking* coal, which is so abundant in the British coal-fields. It occurs above the old red, and beneath the new red sandstone, in what are called the coal-measures. There are several varieties of this coal, such as the *Scotch Parrot coal*, which is of a brownish black colour, and of a slaty structure; it yields a large quantity of gas. There is also the Lancashire *cannel coal*, which burns readily, and hence has been used as *candles*, whence the name. It has a conchoidal fracture, and a waxy lustre. *Newcastle coal* has a full blue-black colour, a brilliant lustre, and a cubic fracture; it burns with a bright luminous flame and yields a valuable coke, superior to that of the other two varieties. Much of the coal of Wales is known as *steam-coal*, the quality of which is intermediate between bituminous coal and anthracite; it burns freely, and gives out a steady heat. It is preferred in the steam-navy, since it does not readily crumble in the hold of the vessel during its rolling, and yields but little smoke, a circumstance favourable to a ship of war in the vicinity of an enemy. *Anthracite*, *stone-coal*, or *culm* contains only a very small portion of volatile matter, so that it burns with a steady red glow, almost without flame. It splinters into fragments when heated, whence it is inconvenient in its use as a fuel; it has a black colour, a high lustre, and a lamellated fracture parallel to the bed from which it is taken.

The fossil fuel of this country was represented in the Great Exhibition of 1851 by the immense block represented in fig. 352. It is a good specimen of the Staffordshire thick or ten-yard coal. Its height was nine feet six inches, the circumference twenty-one feet ten inches, and the weight thirteen tons; it was conveyed seventy yards underground to the bottom of the shaft, and was raised from a depth of 165 yards by the ordinary steam-engine, as shown in fig. 357. The mass of coal represented in fig. 355 was raised from a shaft 459 feet in depth, from Staveley, in the county of Derby. This block was seventeen feet six inches in length, six feet in width, and four feet in thickness. The thickness of the seam was six feet; the cubical fracture of this coal admits of its being split into rectangular masses like bricks, so that it is well adapted for stowage in steamers. Fig. 356 represents the crystalline fracture of certain kinds of Welsh coal.

The coal-fields of our island are usually divided into:—1. The Great Northern District, which includes all the coal-fields north of the Trent. 2. The Central District, including Leicester, Warwick, Stafford, and Shropshire. 3. The Western District, subdivided into the North-Western, which includes North Wales; and the South-Western, which includes South Wales, Gloucester, and Somersetshire. In these fields the coal is separated into a number of distinct layers or strata of various thicknesses, by means of layers or strata of a slaty clay called *shale*, and a coarse hard sandstone called *grit*, forming what are called the coal-measures, as already stated. The strata of coal, called *seams*, are very thin compared with the associated rocks; they extend under large tracts of country, and vary in thickness from a few inches to six or eight feet, except in Staffordshire, where there is a seam thirty feet thick; but this is now nearly all worked out. The interposed strata of grit and shale often exceed 700 feet in aggregate thickness. Under this is the mountain limestone, which rests on the old red sandstone already noticed. These deposits do not occur in horizontal unbroken strata, but have at various times been disturbed by some upheaving force from below, so that the coal-measures in many districts have been made to assume the shape of a huge trough or basin rising on all sides from a central point; the sides of the basin being composed of sandstone or limestone, and the middle filled up with magnesian limestone and new red sandstone. Fig. 353 will convey some idea of the arrangement of the coal-measures, by which it will be evident that the edge or boundary-line of each stratum must appear at the surface, somewhat like the concentric layers of an onion cut in two. This appearance of the coal at the surface is called the *basset* or *outcrop*, or "coming to the day," as the colliers have it. Few coal-fields, however, are bounded on every side by the outcropping of older strata: the upheaving force which converted the horizontal strata into basin-shaped arrangements probably produced certain fissures or fractures, often nearly vertical, and stretching through the whole mass (fig. 354). These rents are called *dykes*, because they divide the seams or bands of coal into fields: they are also called *shifts*, as the miners consider them to have shifted the strata on their sides; but the most common name is *faults* or *troubles*, from their troubling or putting to fault the pitmen.

A coal mine does not greatly differ from the mine already described. A shaft is sunk, and a broad, straight passage, called the *bord*, or *mother-gate* (from the Saxon for *road* or *way*), is driven from it into the seam of coal in opposite directions. This bord is twelve or fourteen feet broad, and of the whole height of the seam, so as to expose the rock above, now called the *roof*, and also the stratum below, called the *thill* or *floor*. A main-level, or *dip-head*, is also driven for collecting the water of the mine: from this gallery other galleries are driven, and the direction of the bords is arranged so as to follow the natural cleavage of the coal which forms their sides. When a bord has been excavated some distance, narrow passages called *head-ways*

are driven from it at regular intervals on both sides; and when these have proceeded eight or ten yards, they are made to communicate with other bords, which are open parallel to the first, and on each side of it. In this way, the bed of coal is laid open and intersected by broad parallel passages, about eight yards apart, communicating with each other by the narrower headways which cross them at right angles, and also traverse the whole extent of the mine, immense pillars of coal being left standing between the two. Fig. 360 represents the plan of one story of such a mine, which is worked by what is called *pannel-work:* the coal is extracted from each pannel in succession, and the large pillars of coal are left between the bords to support the roof: the pillars are next removed, the roof being meanwhile supported by timber props; and when all the coal has been got out, the props are removed and the roof falls in. In fig. 360, *a a* are pannels not entirely laid open by galleries; *b b* are laid open, but the pillars not yet removed; in *c c*, the pillars are being removed and the roof is falling in, its ruins forming what is called *goaf;* the pannel *d* is entirely worked out and abandoned. While the first seam is being worked, the shaft may be sunk to a second or a third seam, where similar operations may be carried on. The regularity of the workings may, however, be disturbed by many accidents. If the roof be of hard sandstone, and the floor of soft clay, the downward pressure may displace and force up the floor; forming what is called a *creep.* But if the roof be soft, it will sink in and form a *crush;* and if both roof and floor are moderately hard and tough, they will gradually meet midway, as shown in fig. 358, filling up the passages. There is also a terrible accident to which the collier is exposed from the escape of an inflammable gas generated by the coal itself; which, mingling with the air of the mine, forms an explosive mixture liable to be fired on the approach of a lighted candle, and spreading death and destruction around. This gas is a compound of carbon and hydrogen (carburetted hydrogen), called *fire-damp* by the miners: when an explosion unhappily takes place, the dust of the mine, consisting, for the most part, of innumerable small particles of coal, undergoes combustion also, forming an irrespirable gas (carbonic acid), called by the miners by the expressive name of *choke-damp,* from its producing spasm of the glottis, and preventing respiration. But as a light of some kind is necessary to the *hewers,* who excavate the coal, and the naked flame is dangerous, light was formerly obtained by the *steel-mill,* fig. 364, by which a stream of sparks was produced by the rapid revolution of a rim of steel against a piece of flint. This contrivance, however, gave but a feeble light, and no real security: candles continued to be used, until several deplorable accidents determined the coal owners to seek the aid of science. Sir Humphry Davy was applied to; and, on investigating the subject, he found that if the flame of a lamp or of a candle were surrounded with wire gauze, the flame would not pass through the meshes to fire the explosive mixture on the outside. Such is the origin of the *Miner's Safety Lamp,* fig. 366, called by the pitmen the *Davy.* George Stephenson was also the inventor of an efficient safety lamp, called by the miners the *Geordy;* but its light was quenched in the lustre of his distinguished rival.

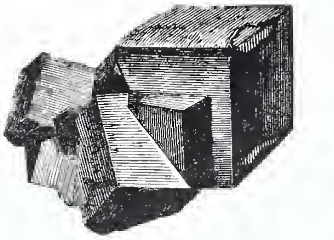
Safety lamps are, however, sources of danger, where men, from constant familiarity with peril, become careless or indifferent. Hence an efficient system of ventilation is now regarded as of as much importance as protected flames. In a mine where there is only a single shaft, provision is made for the ascending and descending currents of air, by dividing the shaft into two portions, as at *a b,* fig. 359, and to begin with two parallel bords, connected at intervals by cross passages, which are successively stopped up by wooden partitions, *c c,* so as to leave no communication except through the one last opened, or that farthest from the shaft: temporary partitions are also placed at *d d,* to cause the current to circulate quite up to the pitmen at W W. In a more advanced state of the works, the direction of the current through every part of the mine, by means of partitions called *stoppings,* becomes a matter of some complexity, as will be seen by the plan, fig. 361, where the arrows represent the course of the air from the *downcast* shaft *a,* through all the galleries to the *upcast* shaft *b.* It will be seen that in most cases the current is allowed to divide itself between the parallel bords; so that if any part of the mine is more *fiery* or dangerous than the rest, from the increased escape of fire-damp, the current can be confined to one course, and thus have its velocity doubled: by which means the dangerous gas is more rapidly drawn out of the mine; while in parts containing but little gas, the same current may be allowed to expand into three passages; such is the system of *double* and *treble coursing. Double stoppings* are also represented in fig. 361; these are pairs of doors, constantly attended by a door-keeper, whose business it is to keep them always shut, except when men and horses are passing through; so as to shut off a dangerous from a more secure part of the mine.

The ventilating current is set in motion by a large fire, which is kept burning at the bottom of the upcast shaft. To prevent the foul air from the more fiery parts of the mine from coming into contact with the flame, it is usual to divide the air as it enters the mine by the downcast shaft *a,* fig. 361, into two distinct currents; one of which proceeds through the passages *e e* into the safest parts of the mine, and the other, *c c,* through the fiery parts, as represented by the lighter shade, including the *goaves,* or abandoned workings, where gas is apt to accumulate. The purer current is allowed to pass through the furnace *f,* before it enters the upcast shaft *b.* The other current is conducted through *d,* and enters the shaft at a higher level, by a channel cut obliquely through the roof of the seam, as in fig. 362, where S represents the upcast shaft, B the impure current, and A the purer current which feeds the furnace; which, in such a case, is called a *dumb-furnace.*

A jet of steam, made to play in the upcast shaft, also acts as a powerful ventilating force. Ventilation is also assisted by erecting towers or chimneys over the ventilating shafts, with large cowls turned by vanes, as in fig. 363, so that one may always present its mouth and the other its back to the wind.

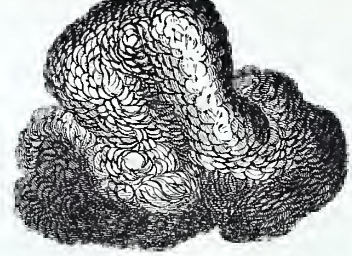
The pitmen are also liable to danger by their ordinary mode of ascent and descent in the shaft, which is usually by a tub suspended by a rope or chain, the breaking of which is not an uncommon accident. To prevent the danger from this source, the apparatus, fig. 365, has been adopted at some pits. It consists of a cage or basket, for the men or the coal, attached to guide-rods or chains down the side of the shaft; and should the rope break, certain springs or arms attached to the top of the cage become liberated and wedged upon guide-rods, whereby the cage becomes fixed. The coal is got out by blasting; and such is the force of two or three *shots* of gunpowder, that from sixty to eighty, or one hundred tons of coal may be brought down at once. The coal is put into *corves* and drawn along tram-roads, by lads called *putters,* to the principal galleries or headways, where it is received into wagons called *rolleys;* a number of which are drawn by a horse to the bottom of the shaft, and the coal is then raised to the surface by steam-power. At the surface, the coal is passed over screens in order to separate the pulverized coal: the screens are usually bars of iron half an inch apart, mounted in a frame-work and sloping so as to allow the coal to slide down into the wagons below. The small coal which passes through the screen is either delivered for immediate sale, or hoisted up and re-screened into *rough, small,* and *dust.* The great demand for coke now allows the small coal, which was formerly waste, to be profitably employed.

The quantity of coal raised in the United Kingdom in the year 1856 amounted to 66,645,450 tons, of which 5,879,779 tons were exported to foreign countries; by far the largest quantity being taken by France.

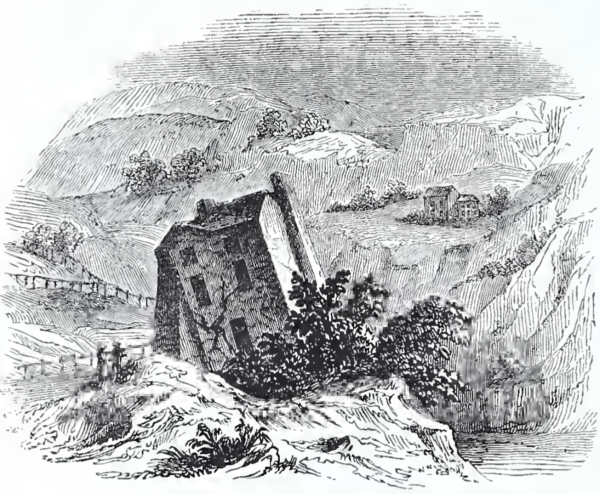


367. IRON PYRITES.

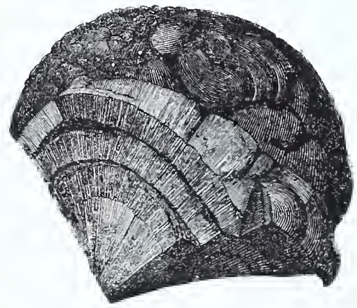
368. COAL AND IRON PIT.



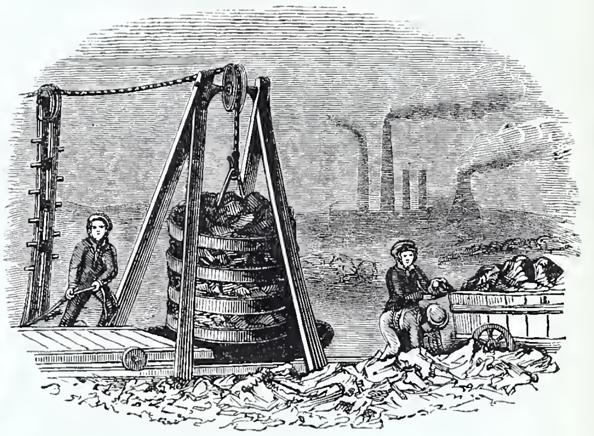
369. SPARRY IRON.



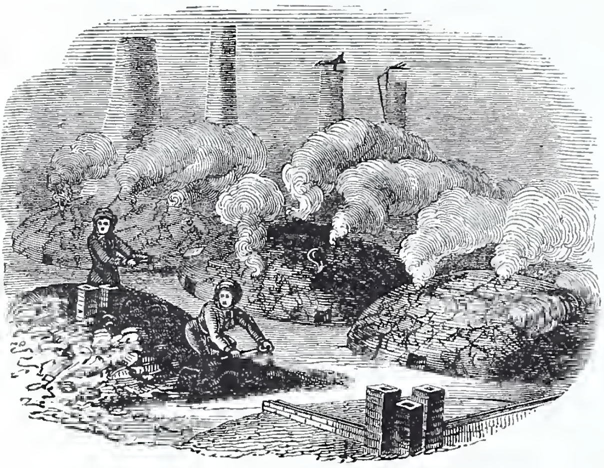
370. EFFECTS OF MINING.



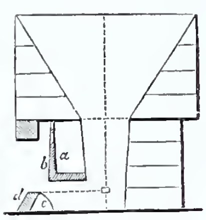
371. HÆMATITE.



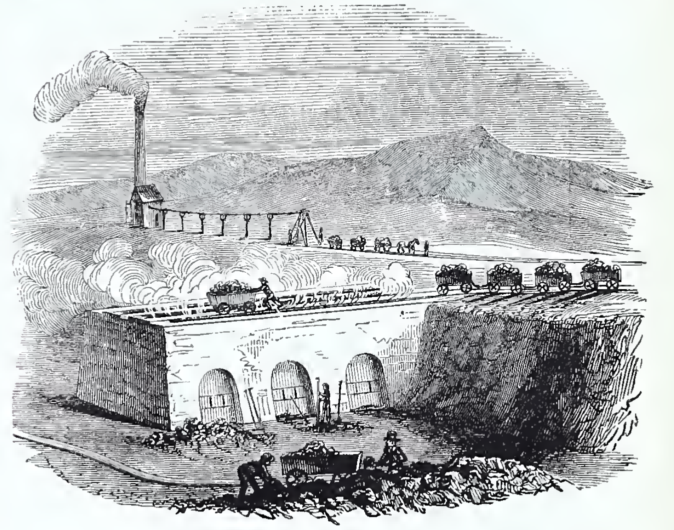
372. MOUTH OF THE PIT.



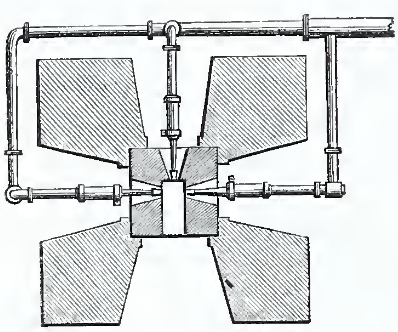
373. ROASTING THE IRONSTONE IN HEAPS.—(*Dudley.*)



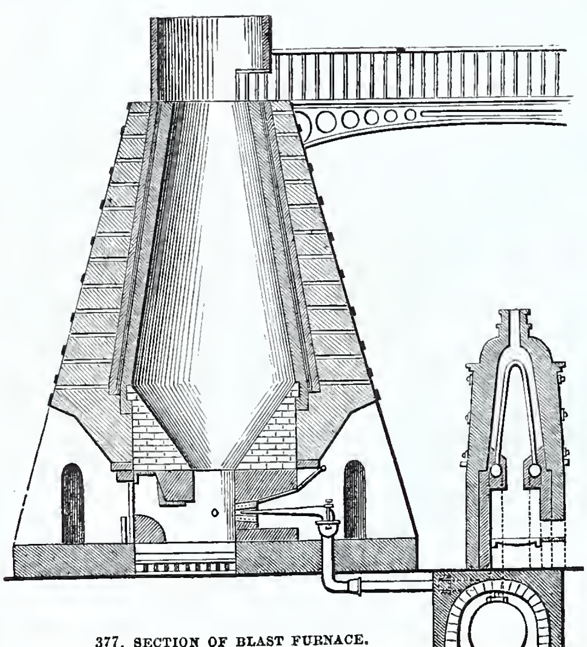
374. LOWER PART OF FURNACE.



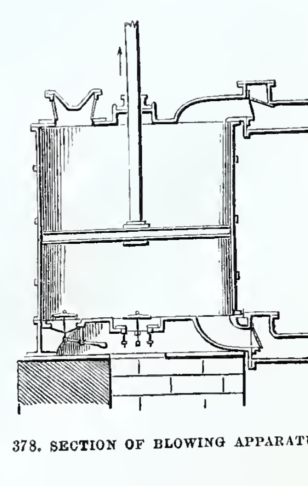
375. ROASTING THE IRONSTONE IN KILNS.—(*Colebrook Dale.*)



376. ARRANGEMENT OF TUYERES.

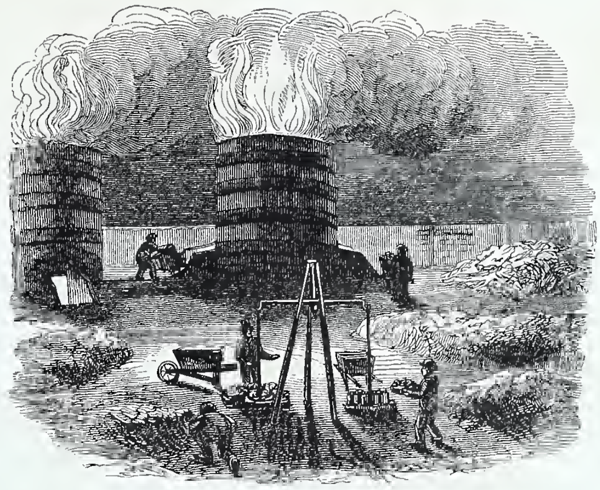


377. SECTION OF BLAST FURNACE.

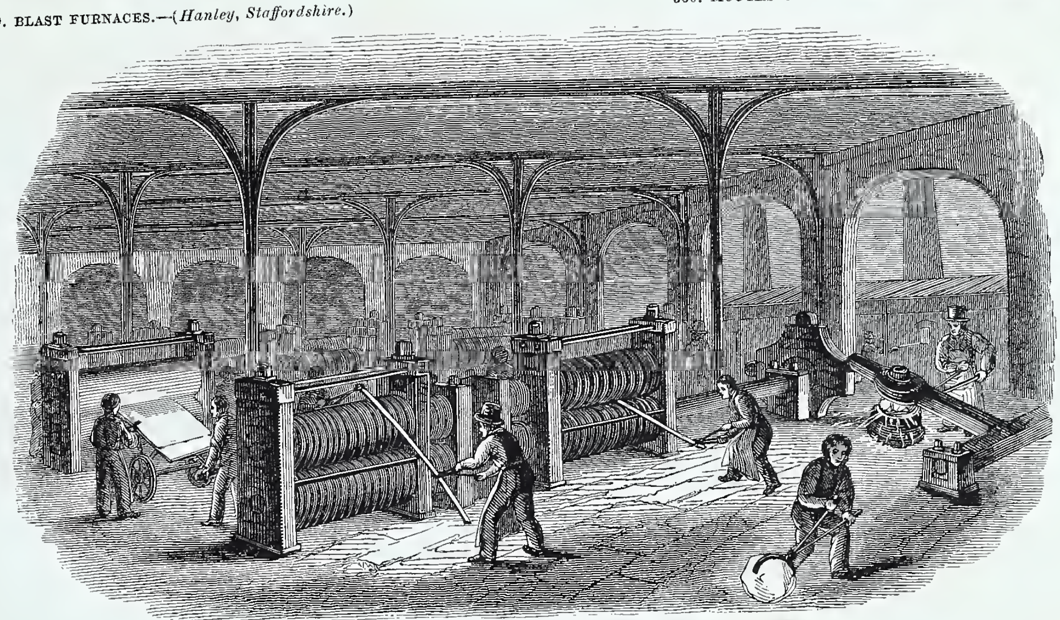


378. SECTION OF BLOWING APPARATUS.

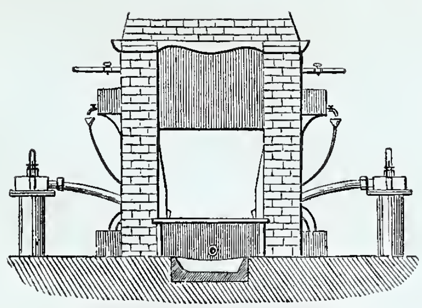
379. BLAST FURNACES.—(*Hanley, Staffordshire.*)



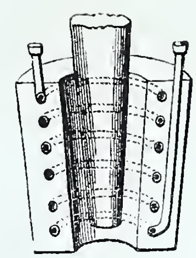
380. MOUTHS OF BLAST FURNACES.—(*Colebrook Dale.*)



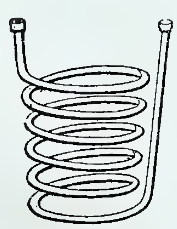
381. THE FORGE.—(*Colebrook Dale Company's Works at Horse Hey.*)



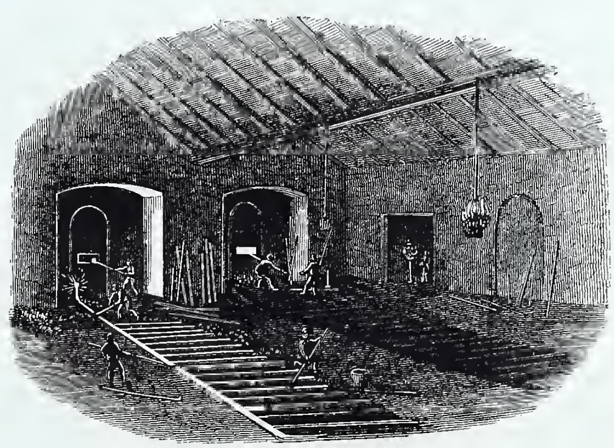
382. SECTION OF REFINERY.



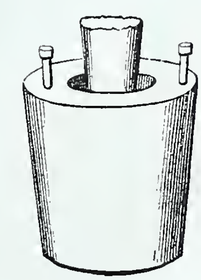
384 B.



384 A. WATER APPARATUS.



383. CASTING.



384 C. WATER APPARATUS

XXIV.—IRON.

The iron-works of Great Britain produced in 1856 the amazing quantity of 3,586,377 tons of pig iron. The innumerable uses to which this truly valuable metal is applied, and the increasing demand for it, at home and in other countries which are not blessed with our sources of mineral wealth, can alone account for this vast production. No other metal represents so many valuable qualities as iron: rendered fluid by heat, it will assume the form of the mould into which it is poured, so that numerous useful articles can be at once prepared by the cheap and ready method of casting: it can be drawn out into bars of any required degree of strength, or into wires of any required fineness: it can be rolled out into plates or sheets: it can be twisted and bent to any required form: it can be made hard or soft, sharp or blunt; the ploughshare and almost every implement of husbandry are formed more or less of iron. There are few machines of which it does not form a part; while those important machines used by the engineer in constructing machinery are mostly of iron. The tools of every mechanic depend more or less upon iron. We travel on iron railways, and are drawn by iron horses; we make long voyages in iron ships; we pass over iron bridges; we sleep on iron bedsteads; we sit in iron chairs; pillars and girders of iron enter into the construction of many houses—sometimes whole houses are constructed of iron; we make lighthouses of iron, and send them in pieces to distant parts of the globe; and, as a worthy conclusion to this suggestive list, we may add that churches of iron are not now uncommon.

Iron exists in the earth in a variety of forms. In combination with sulphur, it is the common *iron pyrites* (fig. 367); but sulphur being an injurious ingredient, this form of the ore is seldom or ever used in the manufacture. The ores most in use are those in which the iron is united with oxygen, such as the *magnetic* iron ore, which produces a bar-iron of great value in making steel; *specular* and *micacious* iron ore, or *iron glance*, are native oxides of iron; and there is also the *hæmatite* or *red iron stone* (fig. 371), which is abundant near Ulverstone in Lancashire, and is much used in making iron for wire and iron-plate. But by far the largest quantity of iron is manufactured from ores which are not rich in iron, but are associated with the fuel required for their reduction. Such is the *clay iron-stone* or carbonate of iron of Staffordshire, Shropshire, Wales, Derbyshire, Scotland, and other parts of Great Britain. It generally contains from thirty to thirty-three per cent. of metallic iron. A specimen of carbonate of iron is represented in fig. 369; but this is a much more favourable example than the dull worthless-looking stone obtained from our pits, in which the oxide of iron, combined with carbonic acid, is mixed with clay, lime, and other earths. The iron-stone usually occurs in horizontal strata or *bands*, and also in lumps, some of several hundred pounds weight, and others not larger than a small bullet. A variety of clay iron-stone known as *black-band*, contains, in addition to the ordinary earthy substances, a quantity of carbonaceous matter which assists in the roasting of the ore.

The Dudley coal basin is an eminent example of the great facilities possessed by this country for the manufacture of iron. Here we find the iron-stone associated with coal, the limestone required for the flux, and the refractory fire-clay used in constructing the interior brick-work of the furnaces. Fig. 368 represents the method of getting out the iron-stone at Dudley. A shaft being sunk, galleries are driven at different depths into the coal, or into the iron-stone. The ore or coal is placed in small wagons moving on a tram-road, and is thus drawn to the mouth of the pit. Here a kind of circular platform is loaded with the stone, the mass being supported by loose flexible bands of iron (fig. 372). When drawn to the top, a platform is wheeled over the mouth, and upon this the load is rested while being unpacked. The extensive excavations thus made underground cause the surface to give way: the walls of houses crack and totter, and are only prevented from falling by building massive buttresses against them, as in fig. 370, which represents a portion of the iron district of Colebrook Dale.

The first operation in the manufacture of iron is *roasting* the ore: this may be done in heaps, or in kilns. When roasted in heaps, a layer of small coal is spread on the ground: upon this a quantity of iron-stone, then more coal: on this the iron-stone is piled into a wedge-shaped heap, and the whole is covered with small coal. In forming the heap, channels are left for the admission of air, as shown in fig. 373. When roasted in kilns (fig. 375), a stratum of coals at the bottom of the furnace is sufficient for the purpose. Coal is also coked by burning it in large heaps.

The furnace in which the iron ore is smelted, is represented in section in fig. 377. It consists of five principal parts, which, reckoning from the bottom upwards, are: 1. The *Hearth*, which is composed of a single block of quartz grit, about two feet square. 2. Upon the hearth is a four-sided cavity called the *Crucible*, slightly enlarging upwards. 3. The part above this is in the form of a funnel or inverted cone, called the *Boshes:* this is the widest part of the interior, above which is 4. The *Cavity* of the furnace, extending in a conical form to the height of thirty feet and upwards. Above this is 5. The *Chimney*. The first three parts are represented separately in fig. 374, with a few more details: *c* is called the *dam-stone*, and *d* the *dam-plate:* from the top of the latter proceeds an inclined plane to allow the scoria to flow off: *a* is called the *tymp-stone*, and *b* the *tymp-plate*, for confining the liquid metal in the hearth; the space under the tymp-plate is rammed with loam or fine clay, called *tymp-stopping*. About two feet above the hearth, there are three openings in the sides of the crucible, for the admission of the ends of blast-pipes, through which air is forced into the furnace. The arrangement of the blast-pipes is shown in fig. 376, while the construction of the blowing apparatus is shown in fig. 378. In the latter arrangement the upward motion of the piston expels air along the top exit-pipe, a portion of which is shown to the right, while the downward motion of the piston expels air along the bottom exit-pipe, and these two pipes thus afford a continuous supply of condensed air to the pipes, fig. 376. It is evident that during the ascent of the piston, air enters by the bottom valves, which open upwards, and that during the descent of the piston these valves remain closed, and the upper valves open. The blast-pipe which enters the furnace is called a *tuyere* (pronounced *tweer*), and is protected from the intense heat by the method shown in fig. 384 A, B, C: a spiral pipe (A), through which a stream of water is kept constantly playing, protects the nozzle of the air-pipe. B is a section of the tuyere, showing the spiral tubing inclosed in cast iron, and C shows the tuyere ready for putting into the furnace. The exact position of the tuyere, and its connexion with the hot-blast apparatus, are shown in fig. 377. Arrangements are usually made for heating the blast of air before it enters the furnace, to the temperature of about 600°, or the melting point of lead. For this purpose, the air is made to circulate through a number of pipes which are heated in the small furnace shown to the right of fig. 377. The advantages of the *hot blast*, as it is called, are the saving of fuel, the use of coal instead of coke in the furnace, and the diminished quantity of flux required. When it is considered that not less than six tons weight of air per hour are injected into a blast furnace of ordinary size, the cooling effect of such an enormous quantity of air must be great; but by heating the air before sending it into the furnace, the saving of

fuel has been found to be such, that $2\frac{3}{4}$ tons of coal are now sufficient for the production of a ton of iron from ore, which would have required eight tons when the cold-blast was used. It is stated, however, that hot-blast iron is inferior in tenacity to the cold-blast.

When such a furnace is regularly at work, it is charged at the top at regular intervals with coal or coke, and a proper mixture of roasted ore and of a lime-stone flux, broken into small fragments. When there is a regular incline from the coke-yard or kilns to the tops of the furnaces, the materials are conveyed in loaded barrows (fig. 380), and turned into the furnace-mouth, or they may be accumulated at that elevation, and weighed out in regulated portions; but in a flat country, the charge is weighed out below, and the barrows are drawn up an inclined plane, as in fig. 379.

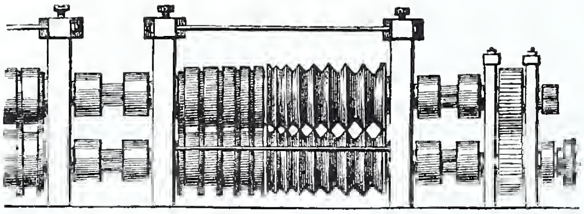
The chemical changes which take place in the furnace are somewhat complicated; but we may here briefly state, that the ore, having been rendered porous by the previous roasting, is readily penetrated by the flame of the ascending gases, and the iron becomes reduced in the upper part of the boshes, where the heat is comparatively moderate. The reduced metal, mixed with the earthy matters of the ore, gradually sinks down to the hotter parts, where the earthy matters melt and unite with the limestone flux into a crude species of glass, consisting principally of the silicates of lime, magnesia, and alumina. In the meantime, the iron in a minutely divided state, coming into contact with the carbon of the fuel, unites with a portion of it, and forms the fusible compound known as cast iron. This carbide of iron melts, sinks down below the tuyeres through the vitrified slags, and is protected by them from the further action of the air. The slag exceeds the iron in bulk by five or six times: it floats above the melted metal, and is allowed to flow off as already noticed, whilst the iron is run off at intervals of eight, twelve, or twenty-four hours.

Drawing off the iron, or *casting*, as it is called, is a splendid sight, imperfectly represented in fig. 383. The shed in front of the furnace is covered with sand to the depth of ten or twelve inches, and, previous to casting, a channel called the *sow* is formed in the sand, extending some forty or fifty feet from the furnace: branching off from the sow at right angles, a number of smaller channels called *pigs* are formed. The hole in the bottom of the hearth being tapped, a river of molten metal rolls slowly on, filling up the large channel, and turning aside into the smaller channels. As the moulds become filled, the surface of the molten metal appears to be in rapid motion; innumerable undulations play upon it, together with beautiful variegations of colour, which cannot be described in words. This refers chiefly to the super-carbonated iron known as *No.* 1, *pig iron.* There are usually six kinds of pig iron. *No.* 1, *No.* 2, and *No.* 3 contain carbon in different degrees; No. 3 is also known as *dark grey iron*, and contains less carbon than the other two. The next quality is called *bright* iron, it being lighter and brighter than the other three. A fifth variety is *mottled* iron, the fracture being mottled with grey and white; while the last variety is named *white* iron, from its silvery-white colour.

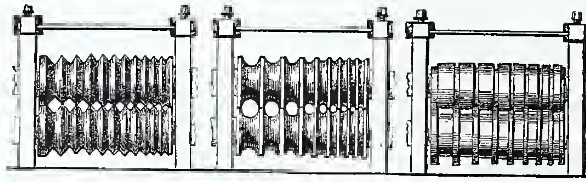
All the varieties of pig iron contain impurities, which render them brittle under the hammer, and unfit for the numerous appliances of the forge. The impurities consist chiefly of carbon, silicium, and minute portions of sulphur and phosphorus. The carbon and silicium are got rid of by exposing the pig iron to a high temperature under the influence of a blast of air, the effect of which is to convert a portion of the iron into an oxide, which, uniting with the oxidized silicon, forms a fusible slag; the excess of oxide of iron in this slag reacts on the melted metal, and, by giving up a portion of its oxygen to the carbon and the silicon disseminated through the mass, an additional portion of these substances is burnt off. Early in the process a portion of the carbon burns off in the form of carbonic oxide, while portions of sulphur and of phosphorus are also got rid of by oxidation, or accumulate in the slag. The furnace in which this operation is conducted is called a *finery*, or *refinery*, fig. 382, the fire of which is urged by a double row of blast pipes, the nozzles of which are kept cool by the water apparatus already referred to. When the melted iron is sufficiently refined, it is run off into a channel, where it solidifies in the form of a flat cake, and it is made brittle by pouring cold water upon it. Coke is the fuel usually employed in the finery; but where a superior iron is required, charcoal is used, the coke containing a portion of sulphur and earthy matters, which injure the quality of the iron.

The refined metal still contains a good deal of carbon and some silicon. To remove these, it is introduced in charges of from four to five hundred-weight into the *puddling furnace*, where it undergoes the operation of puddling. This furnace, represented in section, fig. 392, is what is called a *reverberatory* furnace, the brickwork of the roof being so constructed as to reverberate or reflect the flame of the furnace down upon the charge. The bottom of the furnace is formed of a thick cast-iron plate, protected by a coating of the oxide or cinder formed in previous operations. The chimney is forty or fifty feet high, so as to form a powerful draught, which can be diminished at pleasure by means of a damper. The iron is put in and taken out of the furnace by a large square hole (shown in fig. 387, and also in dotted lines, fig. 392), which, except on such occasions, is closed with a sliding door; at the bottom of this door is a small hole, through which the puddler introduces his tools and inspects his work. The charge, mixed with a proportion of scales of oxide, is first completely fused, then stirred briskly, to mix the oxide with the melted metal, the effect of which is to transfer the oxygen from the oxide to the carbon of the melted metal, and carbonic oxide is formed. This is an inflammable gas burning with a blue flame; its escape produces an appearance of boiling in the metal, and the gas, as it escapes in jets, burns with its characteristic flame. As the carbon diminishes in quantity, the metal becomes less fusible, and at last subsides into a granular sandy mass. The heat is now raised to the utmost; air is excluded from the interior, and the metal soon begins to soften, and to run together, when the puddler gradually collects it into balls, called *blooms*, and subjects each in succession, while still at a glowing heat, to the blows of a massive hammer, called the *helve*, or *shingling hammer*, fig. 389, and also represented, among other operations, in the large engraving fig. 381. This hammer weighs about four tons, and it is lifted by means of a cam, revolving under the nose of the helve. The effect of the blows of this hammer upon the shingle-ball is to squeeze out the liquid slag, to weld the particles of iron together, and to reduce the ball to an oblong shape, fit for the next operation, which is *rolling*. The bloom is still at a bright red heat, when it is passed between a couple of massive rollers (fig. 385), called *puddle-rolls;* the largest hole between the rolls being first used, and the smaller ones in succession, by which means the bloom is rolled out into a bar, or, by passing it between a couple of smooth rollers, into a sheet, as represented in fig. 381. In passing between the rolls, a further portion of the slag is driven off, and the rough bar resulting from these operations is very different in character to the pig iron from which it was produced. The pig iron was hard, crystalline, brittle, and fusible; it is now a long, slender bar of soft, fibrous, tough, malleable iron, fusing with difficulty.

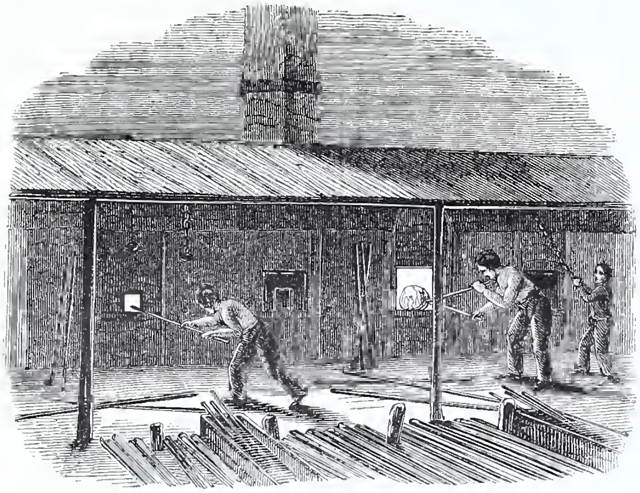
The character of the bar-iron thus produced may be further improved by cutting it up into short lengths by means of powerful shears (fig. 390), and piling several of these pieces upon each other, placing them in a furnace, raising them to a welding heat, and passing them through finer rolls, called the *finishing rolls* (fig. 386). These rolls are of various forms, so as to produce square, round, or flat bars of various sizes. The effect of rolling is to improve the fibre of the iron, and otherwise to exalt the good qualities of the metal. The rolling being complete, the bars are straightened on a long bench of cast iron, then stamped with some letter or foundry mark, and lastly, the rough ends are cut off with the shears.



385. PUDDLE BALL ROLLS.

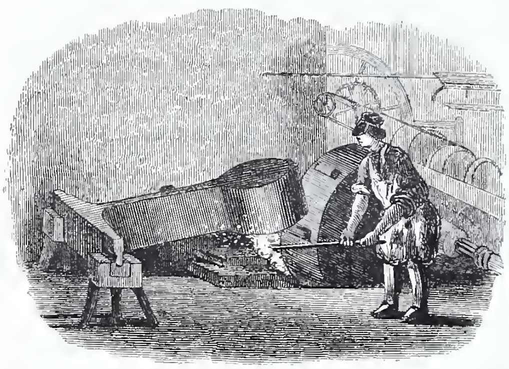


386. FINISHING, OR BAR ROLLS.

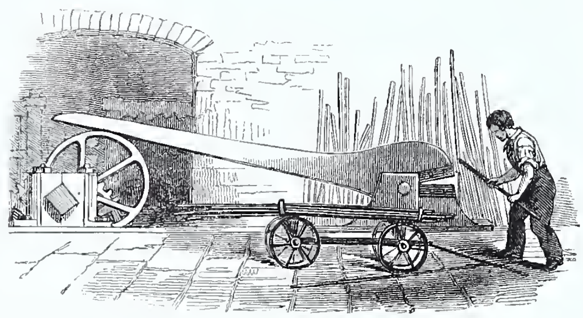


387. PUDDLING.

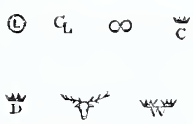
388. MOUTH OF CEMENTING FURNACE.



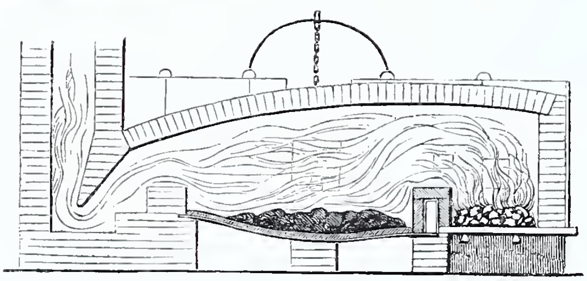
389. THE SHINGLING HAMMER.



390. SHEARS.

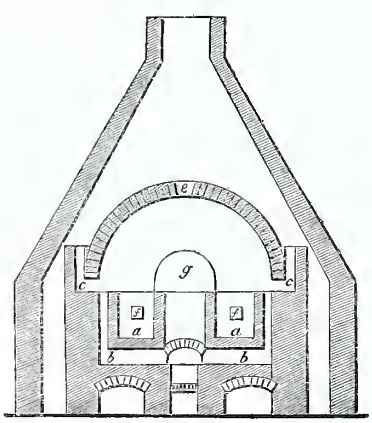


391. OREGRUND IRON MARKS.

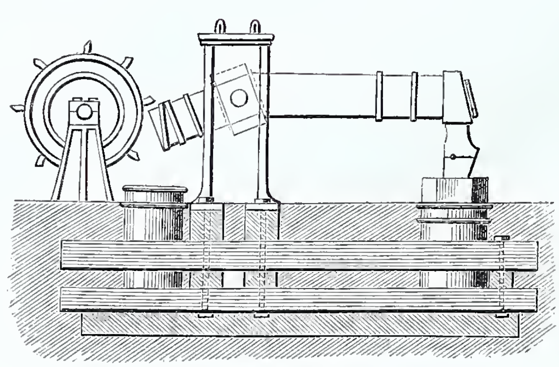


392. SECTION OF PUDDLING FURNACE.

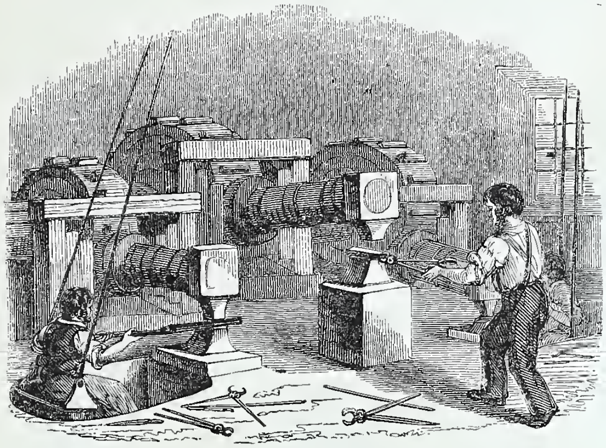
393. FAGGOT.



394. SECTION OF CEMENTING FURNACE.



395. TILT HAMMER.

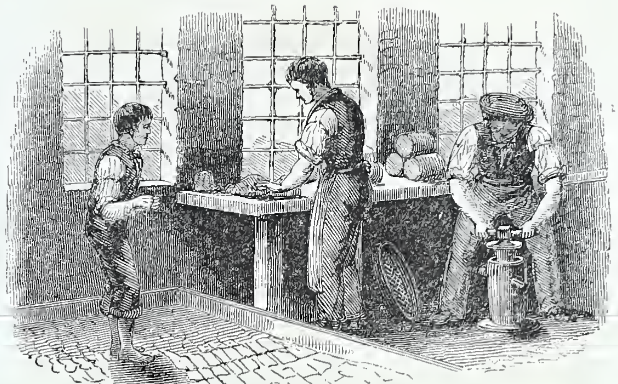


396. TILTING STEEL.

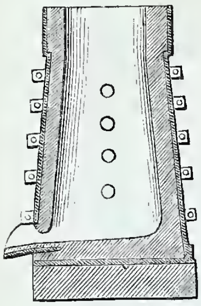
398. MOULD.

399. CORE.

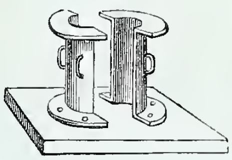
400. CRUCIBLE.



397. PREPARING CRUCIBLES FOR CAST STEEL.



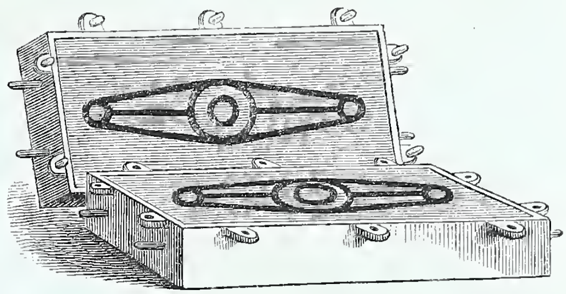
401. SECTION OF CUPOLA.



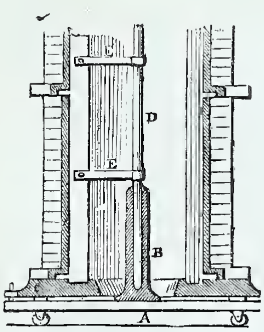
402. PIPE-MOULD.

403. CASTING-POT.

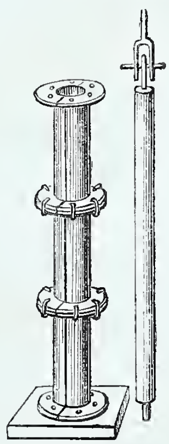
404. DRAWING THE CRUCIBLES.



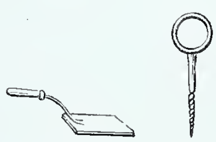
405. FLASK CASTING.



406. SECTION OF MOULD.

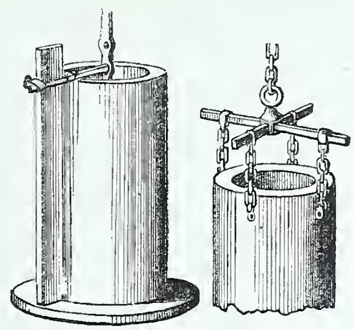


407. PIPE MOULD.



408. TROWEL AND SCREW.

409. RAMMER.



410. CORE.

411. TEAMING.

412. IRON BRIDGE CROSSING THE SEVERN IN COLEBROOK DALE.

The varieties of rolled iron required by our railroad system, iron ships, boiler plates, tires for wheels, &c., are very great. Iron plates require to be rolled of very large size, as, in the construction of the *Great Eastern* steam-ship, some of the plates were twenty-eight feet in length, one and a quarter inch in thickness, weighing two and a half tons each. The iron for plates is prepared by making a pile of rough bars, and, when raised to the welding heat, bringing it under the forge-hammer, where it is beaten into a solid slab, the dimensions of which depend on the weight and shape of the intended plate. It is again heated, and then passed between the smooth rolls, which are at first some way apart, but are gradually screwed closer and closer together. It is brought to the required shape by being passed through the rolls in different directions; and lastly, the ragged and uneven edges are trimmed off with shears.

XXV.—STEEL, AND CASTING IN IRON AND STEEL.

When iron is combined with a smaller proportion of carbon than that contained in cast iron, steel is produced. It is remarkable that a minute portion of carbon, varying from less than one to one and a half parts in one hundred, should confer so many new and valuable properties on iron. It becomes denser than iron, has a finer grain, becomes brighter and whiter in lustre when polished, is more elastic, retains magnetism longer, and does not rust so easily. Steel may also be made so much harder than iron as to be capable of cutting and filing it: steel will scratch the hardest glass, and strike sparks with siliceous stones. But the most valuable property of steel is the facility with which it may be hardened and tempered to almost any degree between extreme hardness and softness.

The refined pig iron of this country is not sufficiently pure for conversion into steel. The hæmatites and other forms of oxide of iron, smelted by a pure fuel, such as charcoal, yield the sort of iron required. Charcoal-iron made at Ulverstone is esteemed; but, perhaps, the best is from the mine of Dannemora in Sweden. Most of the produce of this mine is sent to England, where it is known by the name of *Oregrund* iron, from the port from which it is shipped. This iron is distinguished by one or other of the marks represented in fig. 391, such as the *hoop L*, the *G L*, the *double bullet*, &c. Inferior Swedish iron bears such marks as *C and crown*, *D and crown*, the *Steinbuck*, and *W and crowns*.

Iron is converted into steel in a *cementing-furnace* (figs. 388, 394), a dome-shaped building, surmounted by a hood, as in the glass-house (fig. 276) and the pottery-kiln (fig. 315). Within the furnace are a couple of brick or stone-ware rectangular boxes, *a a* (fig. 394), for the reception of the bars of iron which are to be converted into steel. Below and between the troughs is a grate by which the troughs are heated, the flame being directed round them by the flues *b c*. There is also an opening, *e*, in the middle of the arch. Before the fire is lighted, the bottom of the boxes is covered with a layer of *cement-powder*, as it is called; this consists of powdered charcoal, mixed with about one-tenth of its weight of common salt and wood-ashes. Upon the bottom layer, and at intervals of half an inch, the bars of iron are placed, the spaces between them being filled with the powder; above this is another layer of powder, then another layer of bars; and so on in succession, until the box is nearly full. The remaining space is covered with a layer of damp sand; and the fire being lighted is gradually raised to a full red heat, at which point it is steadily maintained. At the end of each box is a small hole, *f* (fig. 394), called the *tasting-hole*, by which the workman can occasionally draw out a bar to watch the process of the carburation. In about six or eight days the process is complete; the steel retains the form of the iron, but its surface is covered with *blebs* or blisters, which gives it the name of *blistered steel*. Each bar has been penetrated by the carbon; the fibrous texture of the iron has disappeared; so that when broken across it exhibits a fine close-grained texture. It is also rendered more fusible.

The blistered steel undergoes different processes, according to its destined use. To prepare it for forging into edge-tools, it requires to be condensed and rendered uniform by the process of *shearing*, the *shear-steel* thus produced being originally employed for making the shears for cutting off the wool of sheep. The process is also called *tilting*, on account of a tilt-hammer being used. The *tilt-hammer* (figs. 395, 396) is arranged so as to give a rapid succession of blows, by causing the cogs of a wheel to play upon the tail of the helve. In this way the hammer-head may be made to fall with considerable force on the anvil, as many as from 150 to 160 strokes per minute. The blistered steel is prepared for tilting by breaking the bars into lengths of about eighteen inches, and binding four or more of these into a fagot (fig. 393). This, being raised to a welding heat, is placed under a forge-hammer, similar to fig. 389, which unites the different portions and closes up internal cavities. The rod thus produced being again heated, is passed under the tilt-hammer, the rapid blows of which revive the heat, so that the rod ignites under the strokes. The workman, seated in a kind of swing (fig. 396), advances or recedes with rapidity by a slight motion of his foot, and he quickly converts the rude steel rod into a smooth, sharp-edged prism, which can be forged into shears, edge-tools, and cutting instruments.

The best kinds of cutlery are formed of *cast steel*: that is, the blistered steel, being fused and cast into ingots, becomes more uniform in texture, and of superior quality, from the more equal distribution of carbon throughout the mass. The melting-pots or crucibles are made of Stourbridge fire-clay: this, being mixed with water, is spread out in a shallow trough on the floor, where it is kneaded during several hours by the naked feet of two men (fig. 397). The crucibles are formed in a wooden mould (fig. 398), which being rammed full of clay, the core (fig. 399) is forced into it, when a pot of the form represented in fig. 400 is produced. This is removed from the mould, and placed near the furnace to dry. Each furnace is large enough to contain two crucibles; the fuel is well-made coke, and a powerful draught is maintained by means of a tall chimney. Eight or ten of these furnaces are placed side by side, and they communicate by means of trap-doors with the casting-shed above. The bars of blistered steel are broken into fragments, and the charge for each crucible is weighed out, with the addition of a small portion of black oxide of manganese, which is supposed to improve the quality of the steel. Each pot is charged by means of a long iron funnel, let down into it while glowing with the heat of the furnace. A cover is then put on, and the fire is kept well supplied with fuel. In about four hours the steel is ready for casting: each ingot-mould is about two feet long and two inches square; it is made up of two parts, fitting accurately, and held together by a clamp of iron. It is kept upright by resting against the angles of a pit in the floor. Before putting the parts of the mould together, the interior is smoked over a fire of pitch, to prevent the liquid steel from adhering to or melting the mould. Just before drawing the crucibles, a man puts on sacking leggings and a coarse apron, drenches them with water, and then, throwing up the trap-door, strides over the fiery furnace (fig. 404) and raises the crucible

by means of tongs. A second man immediately removes the cover, while a third grasps the crucible with tongs applied to the side, raises it, and pours the glowing metal into the mould amidst a bright scintillation of sparks (fig. 411); the other man keeping back with a rod any portions of cinder or slag which may be on the surface. The ingots solidify immediately, and are removed from the mould; while the crucibles are returned to the furnaces for another charge.

The conversion of iron into various useful forms is brought about by one of two great series of operations, conducted either in the forge or in the foundry. In the forge, pig iron is converted into malleable bar iron, which can be further shaped into different forms by processes which will be noticed hereafter. In the foundry the pig iron is melted, and reproduced in various shapes by casting in moulds. In this process it still retains its brittleness, and does not acquire the valuable fibrous texture which allows it to be beaten out under the hammer.

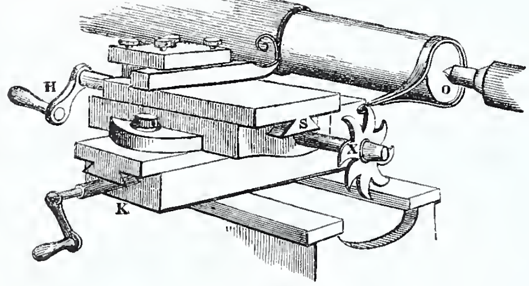
The founder has to mix several qualities of iron, according to the nature of his castings; one piece may require strength and tenacity to bear heavy weights and strains; another must yield readily to the file or the chisel; a third may require to be hard; a fourth to resist sudden changes of temperature; and so on. The mixture of pig iron is melted in a small blast furnace called the *cupola* (fig. 401): this is a cast-iron cylinder, lined with sand or fire-bricks, with openings at various heights in the side for admitting the blast-pipe where it is wanted. Near the bottom is an opening for letting out the liquid metal. The furnace is first filled with ignited coke, and as this begins to sink, alternate charges of coke and pig iron are thrown in every ten or fifteen minutes.

In executing an article in cast iron, a wooden pattern is first made, about one-eighth of an inch per foot larger than the intended object, in order to allow for the contraction of the metal in cooling. There are three varieties of casting:—1st, in moist or green sand; 2d, in dry sand; and 3d, in loam. The first and second methods resemble each other: only the one is intended for fine work, and the other for coarser articles. Green sand is a mixture of fresh sand with about one-twelfth of charcoal, made a little moist, that it may preserve the forms impressed in it. The mould is formed within a couple of iron frames, without tops or bottoms, called *flasks* (fig. 405), furnished with handles for lifting, and with pins and holes for accurately fitting into each other. The lower flask is placed on a board, and is filled with sand well rammed down with a *rammer* (fig. 409). The pattern is then pressed down into the sand until it is half buried, and the sand is smoothed up the sides of the pattern with a small *trowel* (fig. 408). The other flask is now put on, and fine burnt sand or charcoal, called *parting-sand*, is dusted over the surface last prepared to prevent it from adhering to the sand which is now to be put into the upper flask. Channels are also moulded on the lower surface for the introduction of the melted metal. These channels are made by burying some rods of wood, extending from the pattern to the side of the frame. The upper flask is now filled with sand and well rammed down, the rods of wood are removed, the upper flask is lifted off, and the pattern carefully taken out by inserting at each end the point of a screw (fig. 408). Defects in the mould are repaired with sand; and the surfaces being dusted over with fine charcoal, the upper flask is carefully placed in its proper position: and the two being set up on end, the molten metal is brought from the cupola in an iron ladle or pot lined with loam, and is poured into a channel left in the flask for the purpose. The escape of air and of the steam produced by the hot metal is usually facilitated by driving a small iron rod into the sand in various directions from the pattern before the latter is removed. Casting in dry sand is similar in principle to the foregoing. By this method are produced the various pots and pans, ranges, frames for machinery, spandrils for roofs, and similar articles, which do not require a central core. We may also refer to the bridge (fig. 412), as a specimen of the first iron structure of the kind ever erected, and to the iron dome in the Crystal Palace (fig. 418), as specimens of the earliest and latest structures in cast iron, in which the parts are cast separately, and put together as in any other building.

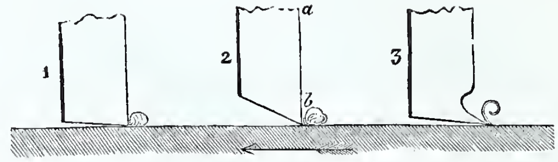
In casting hollow tubes, such as water-pipes, the half-cylinders (fig. 402) are used: these are set up on end, and a smooth plug, of the exact size of the intended pipe, being passed through the centre, is supported by a pin passing into a hole in the floor, and is fastened above by the contrivance shown in fig. 407. The intervening space is filled up with moist sand, when a second pair of half-cylinders is added to the first, and sand is rammed in as before; a third pair is added to the second, and more sand added: this completes the length of nine feet, or that of a cast-iron water-pipe. The plug is now carefully withdrawn, and the cylinders, with their lining of sand, removed to the drying-stove. A core is next formed by winding hay or straw round a four-sided bar, and covering it with mortar to the exact size of the intended core, or interior of the water-pipe. When this is solid, the core is drawn out and well dried. The cylinders, with their lining of sand, are now set up in a pit; and the core is carefully adjusted so as to fill up the sand tube, with the exception of a space between the outer surface of the core and the inner surface of the sand, which evidently gives the thickness of the intended pipe. A quantity of molten metal is then poured in so as to fill the space; and when this is cool the mould is hoisted out of the pit, the outer cylinder is removed, the core is taken out, and the pipe, supposing the casting to be perfect, is ready for use. The *casting-pot* (fig. 403) is used for conveying the metal from the cupola; the use of the double handle is for tilting it over in the pouring.

Loam-casting on a large scale, such as the cylinder of a steam-engine, is similar in principle to the method last described, but the details are different. Fig. 406 is the section of a mould for a large cylinder. It is placed upon an iron frame (A), mounted on wheels: in the centre of this frame is fixed a tube (B); C is a ring of iron, with four ears or flanges for the purpose of lifting it; this ring is placed on the frame A, as nearly as possible concentric with the tube B. On this ring a thickness of sand is first placed, and upon the sand a cylinder of brickwork is constructed, clay or wet loam being used instead of mortar. The inner diameter of this cylinder exceeds by a few inches the outer diameter of the intended casting. The inner surface of the brick cylinder is therefore covered with loam, and is made to assume the exact shape of the outer surface of the casting by the following contrivance:—A rod (D), furnished with arms (E), is dropped into the tube B; and to these arms is attached a piece of wood properly shaped, and this, by revolving on its centre D, moulds the wet loam to the shape of the cylinder. This outer mould, now completed, is moved to an oven to be dried, or a fire is kindled within it. The central core of brickwork (fig. 410) is formed in a similar manner; only the outer surface is covered with loam, and made to assume the shape and dimensions of the inner surface of the cylinder by placing the mould-board on the outside. The core is also made dry by being baked: the mould is now lowered into a pit by the cross-piece and chains shown in fig. 410; and when the core is properly adjusted and filled with sand to give it steadiness, a flat cover of dried loam is put over the whole, openings being made in the cover for pouring the metal. Channels are now made in the sand which covers the floor of the casting-house, so as to connect the furnace with the pit; and when everything is prepared, the furnace is tapped, and the metal flows into and occupies the space between the inside of the mould and the outside of the core, forming, in fact, the cylinder required. Letters, figures, &c., in relief, required on the outside of the cylinder, are previously sunk into the loam which forms the inner lining of the mould.

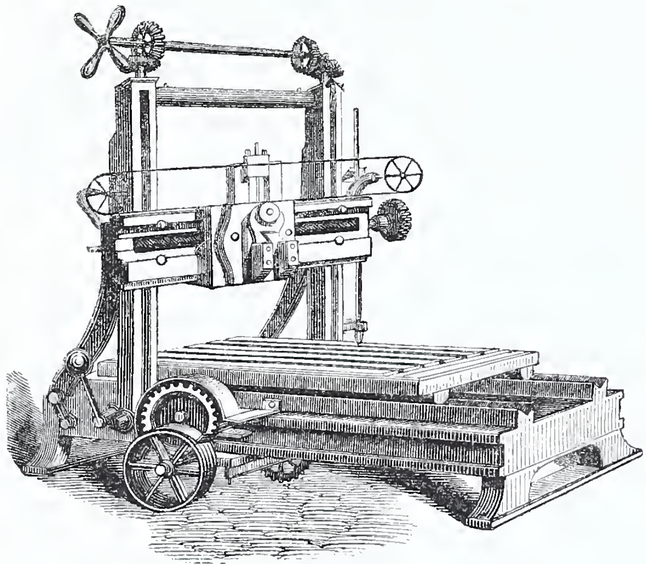
413. IRON SHAVING.



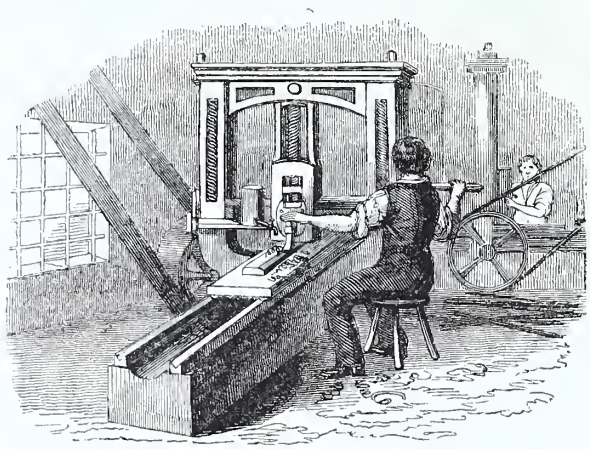
414. THE SLIDE REST.



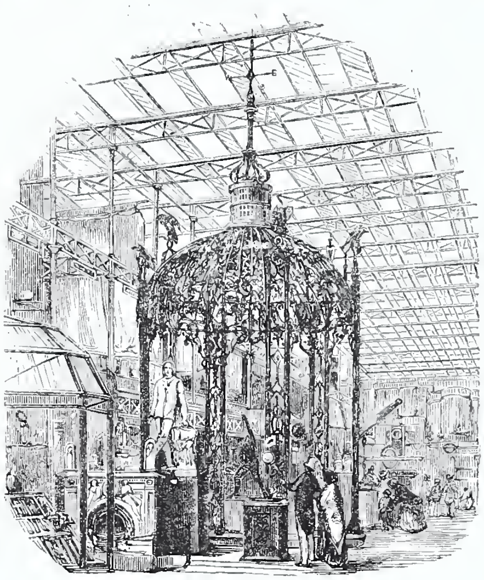
415. BAD AND GOOD CUTTING TOOLS.



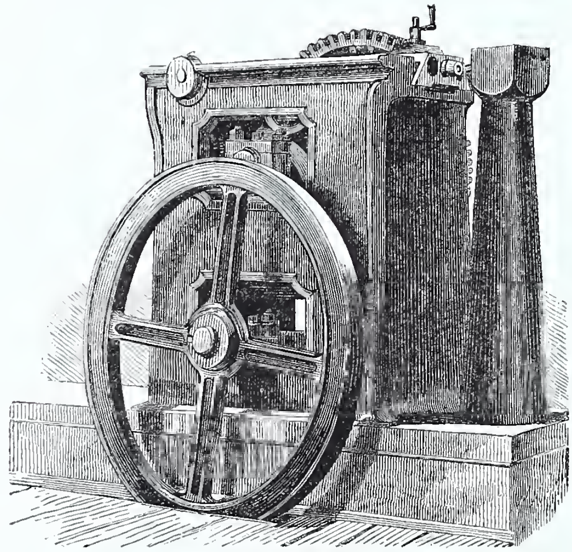
416. PLANING MACHINE



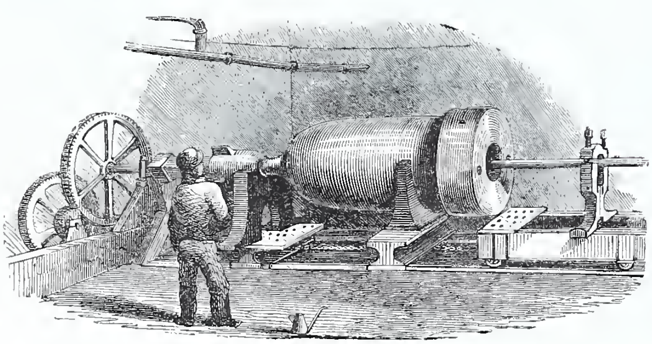
417. PLANING MACHINE.



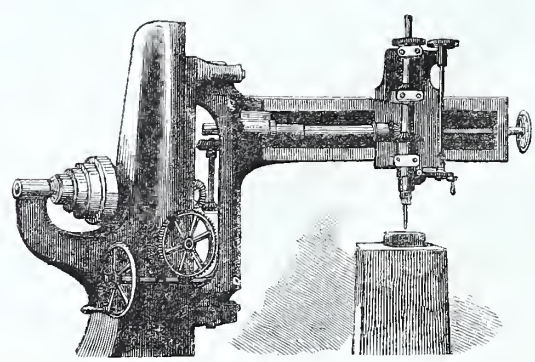
418. THE IRON DOME.



419. RIVETING MACHINE.



420. BORING MACHINE.



421. DRILLING MACHINE.

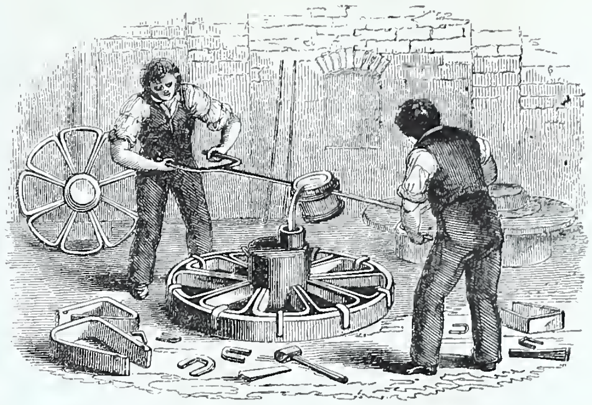
422. BENDING THE TIRE FOR RAILWAY-CARRIAGE WHEEL.

430.

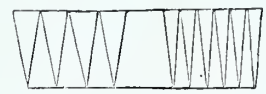
431.

432.

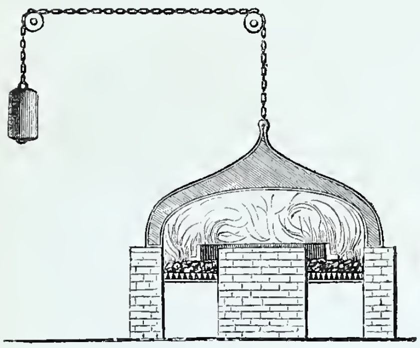
433.



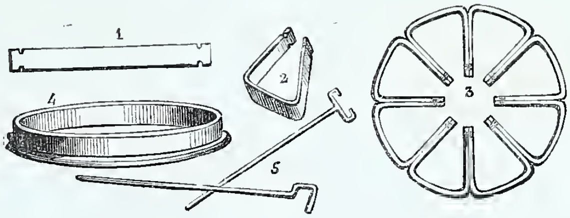
423. CASTING THE NAVE OF RAILWAY-CARRIAGE WHEEL.



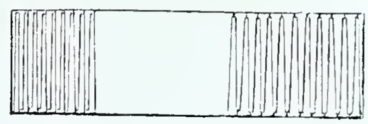
440. ILLUSTRATIONS OF CUT NAILS.



424. RING FURNACE.



425. TOOLS AND SEPARATE PARTS OF WHEEL.

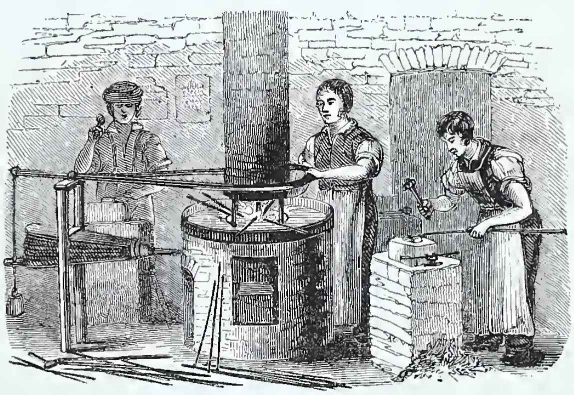


441. CUT NAILS.

434.

435.

436.

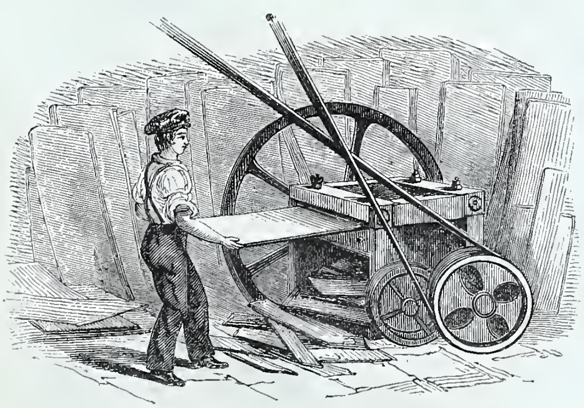


426. NAIL-FORGE.

437.

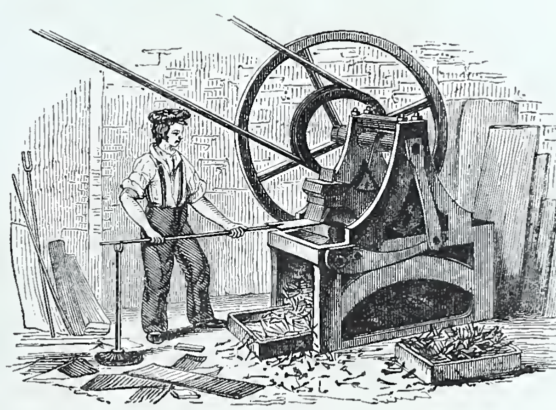
438.

439.



427. PREPARING STRIPS.

428. MOUNTED STRIP.



429. CUTTING NAILS.

XXVI.—MANUFACTURES IN IRON.

The processes, both of the forge and of the foundry, which are such prominent features in an engineer's workshop, are liable to continual variation as new machines and applications of machinery come into use. Thus the railway system, which has not yet been in existence much more than a quarter of a century, has led to the important and extensive profession of railway engineering. The enormous demand for steam-engines, locomotives, rails, and railway carriages has led to the introduction, or at least the improvement, of many powerful machines for turning, planing, punching, drilling, and boring masses of iron with as much facility as the carpenter performs those operations on wood. Few contrivances in the engineer's workshop are more beautiful than the *slide-rest*, fig. 414. Before its introduction, nearly every part of the machine had to be made and finished by manual labour; so that we were dependent on the dexterity of the hand and the accuracy of the eye of the workman for the production of parts of an engine or of a machine, which often require for their efficiency to be exactly of the same shape and size; while single parts were required to be true,—a cylinder, for example, to be really cylindrical, and a plane surface level. The steam-engine owes its present perfection to the means possessed by the engineer of giving to metallic bodies precise geometrical forms. It is evident that we could not have a good steam-engine, if we had not the means of boring out a true cylinder, or turning a true piston-rod, or planing a valve-face.

The slide-rest is an appendage to the turning-lathe, so contrived as to hold a tool firmly to the work; and while cutting a shaving from the bar in the lathe, the tool is slid gently along, and the bar is turned quite true. In fig. 414 the tool is held firmly in a sort of iron hand or vice, which is made to move in the required direction by means of the slide S, the sliding motion being given by the workman, by turning the handle H, while the depth of the cut is regulated by the under-slide K, also moved by a screw-handle. By the separate or combined motion of these two slides, the tool can be made to act along or across the work with great accuracy: the attendance of a workman may even be dispensed with by attaching a star (X) to the wheel (H), and an iron finger to the end of the work in the lathe at O. As the work revolves, the finger will bear down one of the points of the star, the effect of which is the same as turning the screw-handle H, by which the tool is moved along the surface of the work.

In this way cylindrical forms are obtained in metal with great accuracy. The *planing-machine* (figs. 416, 417) is an application of the slide-rest to plane surfaces. In cases of this kind, the form of the cutting-tool is of great importance. If in fig. 415 the shaded portion represent a surface of iron, from which it is desired to cut off shavings, either by moving the iron against the tool in the direction of the arrow, or by moving the tool over the surface of the iron in a contrary direction, a tool of the form shown in No. 1 would not do its work: the particles of the metal would not be cut, but only rubbed or crushed off by sheer force, since in this case the cutting edge is so blunt that it forms a right angle with the face of the iron. In No. 2 the same objection applies even with greater force; for not only does the tool act at right angles to the surface to be cut, but its form gives it a penetrating action in the direction *a b*, which will produce a number of teeth-like marks. In No. 3, however, the cutting edge is in the direction of the strain or cut, and this edge is also arranged with reference to the greatest strength, the mass of metal behind the edge giving it firmness and support. In such a case the shavings are turned off in the form of curls, fig. 413, without any tendency to *chatter* or produce a rippled surface. In forming and setting a tool to cut any surface, the end of the tool must be so placed as to form the least possible angle with the surface to be cut.

In the planing machine the work is firmly bolted to a table, sliding in dove-tail grooves, and travelling backwards and forwards under the cutting-tool, which admits of accurate adjustment. When one end of the work has escaped from under the tool, the table is moved back, and the slide-rest is moved a little way across the table so as to take off the next shaving close to the one previously cut. It is necessary to keep the tool cool during the work, by allowing cold water to drip upon it, otherwise the edge would soon become soft.

The *boring machine* (fig. 420) is another contrivance of a similar kind. Boring is but a branch of turning, only in the former the tool is usually made to revolve while the work is at rest, while in the latter the work revolves while the tool is at rest. There are, however, exceptions to this: in boring cannon, which are cast solid, the gun is made to revolve, while the borer advances on a fixed axis, or in heavy ordnance the gun may be fixed while the cutter revolves. The arrangement in fig. 420 represents the boring of one of the cylinders of the hydraulic press, by which the Britannia Tubular Bridge was raised. In boring the cylinders of steam-engines, the working-barrels of large pumps, &c., the cylinder is cast hollow, and the cutters are arranged round the rim of a cutter-head of cast iron, attached to a tube, accurately fitted on an axis, and moved through the cylinder by machinery in such a way that sixty turns of the axis may cut one inch of the cylinder.

In making the boilers of steam-engines and other structures in which sheets of iron are held together by bolts or rivets, which, being inserted red-hot into holes, pass through the overlapping edges of the iron plates, the hot bolt is crushed up by means of powerful hammers, amidst a deafening noise and a large amount of labour. In Mr. Fairbairn's *riveting machine*, fig. 419, the work is done by an almost instantaneous pressure, and without any noise. In this machine the boiler or other work is suspended between a die on the upright post; when a moving slide and die, worked by the action of a revolving cam upon an elbow-joint, closes the work and finishes the rivet. By this machine the cylinder of an ordinary locomotive engine boiler, eight feet six inches long and three feet diameter, can be riveted and the plates completely fitted in four hours; whilst to execute the same work by hand would require twenty hours. The *drilling machine*, fig. 421, is a contrivance for giving rotatory motion to a drill; and by means of spur gear, connected with the arm, moving the tool to and fro, or up and down. It is used for drilling holes in metals where accuracy is required, the rougher work being done by the punching machine.

We can do no more in this place than just name such important engineering tools as the *steam hammer*, the *self-acting slotting and shaping machine*, the *drilling and boring machine*, the *punching and shearing machine*, the *bolt-head and nut-shaping machine*, the *wheel-cutting and dividing machine*.

Railway-carriage wheels.—As a specimen of the work done in a railway engineer's workshop, we may here describe the method of making railway-carriage wheels. A straight bar of *angle* iron (rolled so that its section forms a right angle) is raised to a red heat, and then curved round a circular maundril by the contrivance shown in fig. 422: one end of the bar being secured by a staple to the maundril, the bar is bent round by levers, shown separately at No. 5, fig. 425, and also with the assistance of a sledge hammer; and the two extremities of the bar are united by driving between them a couple of wedges of iron at a welding heat. The tire is then put into a *ring-furnace* (fig. 424), and the spokes are prepared by bending a wrought-iron bar (No. 1, fig. 425) into the form represented at No. 2, and eight of these bent bars are arranged into a complete set of spokes, as in No. 3. These are all united by the

nave, which is cast solid, for which purpose the spokes are fixed within a maundril, as in fig. 423, their centres terminating in flasks, in which the proper shape of the nave has been moulded. Molten metal is poured in, after which the spokes and nave are inserted within the tire, which is too small for the purpose until it has been heated and stretched ; for which purpose the tire is taken out of the ring-furnace, and placed, while still hot, in a *stretching machine*, in which a number of blocks, forming segments of the circle required, are thrust out by means of a hydraulic press so as to stretch the hot tire sufficiently to allow the arrangement of spokes and nave to drop in. This being done, the tire is left to cool, and in doing so closes in upon the spokes, binding and compressing them firmly; the whole being finished by a rivet through each spoke into the tire.

Nails.—When William Hutton, the historian of Birmingham, in the year 1471, first approached that city from Walsall, he was surprised at the prodigious number of blacksmiths' shops upon the road ; and could not imagine how the country, though populous, could support so many people of the same occupation. In some of these shops females were observed wielding the hammer ; and being struck with the novelty, Hutton inquired whether the ladies in that country shod horses ? He was told, with a smile, that they were *nailers*.

Such was the condition of most of the useful arts in this country, in the middle of the last century. Articles in common every-day use were produced by individual efforts, or handicrafts. As the demand for any particular article increased, and the supply did not keep pace with the demand, wages rose, and the trade was said to be flourishing. But as the religious and mental culture of the workman, if attended to at all, did not keep pace with his worldly prosperity, he was accustomed to spend his gains in carrying his so-called pleasures to excess; and, though earning good wages, his wife and children seldom shared in the prosperity. In the case of the nailer, as the husband would not work longer than he was compelled to do, his wife and daughters, easily acquiring the simple art, would continue the exertion until enough had been earned to pay the week's expenses. The nailers, never dreaming of being competed with by machinery, dictated their own prices ; or, working under one master, would strike for higher wages, until at length, by the slow but accumulating effect of many different circumstances, machinery, in this as in so many other cases, came to perform the work of men's hands. For many a long year did the nailer continue to struggle against the machine ; and the wife and daughter, who had formerly learned the occupation from choice, continued to exercise it from hard necessity ; wages fell lower and lower, until at length the nailer's trade came to be one of the lowest and most despised. Some descriptions of nails are still made by hand ; but the great bulk of those for which there is most demand, are easily and cheaply cut out of sheets of metal by machinery.

Nails are forged by hand from rods of wrought iron of suitable size. There are not less than 300 different sorts of nails, with at least ten different sizes of each sort. The nailer's apparatus consists of a small hearth or forge, for bringing the iron to a proper heat, an anvil, a hammer, and one or two other tools. The forge represented in fig. 426 is of an improved kind, but does not require particular description. The nailer begins work by putting the ends of three or four nail-rods into the fire, and working the bellows to bring them to the proper heat. He next takes one of the rods out of the fire, and resting it on the anvil, forges or *draws out* the nail by a few skilful blows, and cuts it off from the rod by means of a chisel called a *hack-iron*. If the nails are of moderate size, the end of the rod is still sufficiently hot to allow another nail to be forged from it, before returning it to the fire. The next operation is to form the heads of the nails cut off: this is done by a tool called the *bore;* this is a piece of iron, furnished at each end with a steel knob, perforated to the size of the shank or hollow of the nail, and countersunk so as to correspond with the head. Taking up a nail while very hot with a pair of tweezers, and inserting its point downwards into the bore, the nailer strikes it with a hammer upon the projecting end, which forces it to take the shape of the perforation.

Some of the principal forms of nails are represented in figs. 430—439. Fig. 430 is called *rose-sharp*, and is much used for coopering, fencing, and other coarse purposes, where hard wood is used. A thinner sort, called *fine-rose*, is used in pine and other soft woods, the broad-spreading heads serving to hold the work down. Fig. 431 is the *rose*, with *flat* or *chisel* points, which, being driven with the edge across the grain, prevents the wood from splitting. Fig. 432 is the *clasp*-nail, from the form of the head, sticking into the wood and clasping it together : it is much used by house-carpenters. *Clout*-nails (fig. 433) are used for nailing iron-work and various substances to wood: the *counter-clout* (fig. 434) is countersunk under the head, and has a chisel point. Fig. 435 is called *fine-dog*, to distinguish it from a thicker nail, called *strong* or *weighty-dog*. Fig. 436 is known as the *Kent hurdle;* fig. 437 is the *rose-clench*, used in ship and boat-building : it is called clench from the method of hammering down or clenching the end over a small diamond-shaped plate of metal, called a *rove*. *Horse*-nails are made so that their heads may lie flush in the groove made for them in the horse's shoe. *Brads* (fig. 439) form a large class of useful nails, a remark which also also applies to *tacks*.

It is easy to see that nails or brads in the form of simple wedges can easily be cut from a strip of iron, as in fig. 440; where the stronger sections represent that form of shoe-nail, called a *sparrable* or *sparrow-bill*, from its resemblance to the mandible of a familiar bird, the slighter sections in the same figure being named *sprigs*. By a little contrivance, it is not difficult to cut both brads and headed nails out of a flat strip of metal without any waste ; as will be seen by reference to fig. 441, all that is necessary being to turn over the strip after each cut, so as to make the heads and points of contiguous nails fit into each other.

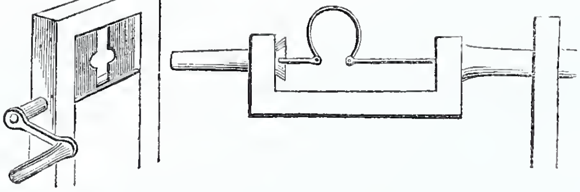
The iron from which nails are cut, is in the form of sheets or plates of the proper thickness : these sheets are cut into strips of the required size, by means of a powerful *cutting-press*, fig. 427. Each of these strips is then mounted on a rod (fig. 428), and is held in the *nail-cutting machine* (fig. 429), the further end of the rod being supported on a forked rest in order to keep the strip in a proper position. The nail-cutting machine contains a couple of steel dies, or a punch and a die, by which a nail is cut off whenever the strip is presented ; but as every cut leaves the end of the metal oblique, in consequence of the shape of the nail, the strip must be turned over after every stroke. The machine works with great rapidity, often making as many as 160 strokes in a minute. There are several forms of the nail-cutting machines: in one of them, after the nail is cut off from the strip, it is caught by a clasp and exposed to a strong pressure, whereby a head is produced much in the same way as in the operation of forging.

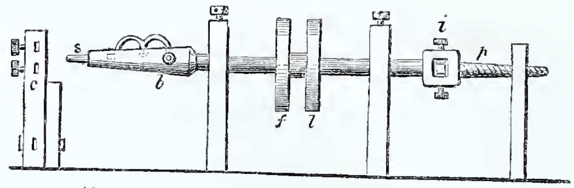
Machine-made nails require to be annealed: the strong compression to which the iron has been subjected in rolling and in cutting and punching, hardens the metal so as to produce an amount of brittleness which requires to be removed: this is done by putting the nails into close iron boxes, heating them in ovens, and allowing them to cool gradually: they are lastly packed in strong hempen bags, or are made up in bundles or in casks, according to the market for which they are destined.

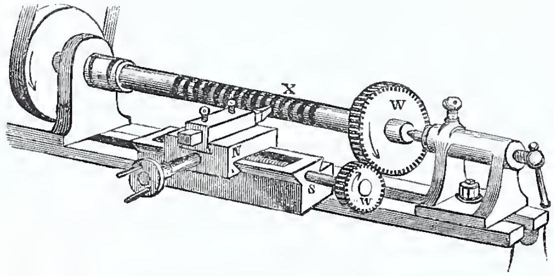
Screws.—The screw, also called the *screw-nail*, but more commonly the *wood-screw*, from its use by carpenters for fastening pieces of wood, or of wood and metal together, is a neater fastening than a nail, and is used in many cases where a hammer could not be applied.

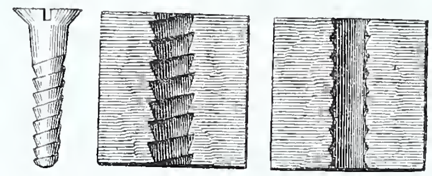
Blanks for screws were formerly forged by the nailers ; but screw-making has long since passed into a factory operation, and as such we shall describe it.

In making screws of the most common sizes, a coil of wire is arranged so that it can be drawn into the blank-making machine

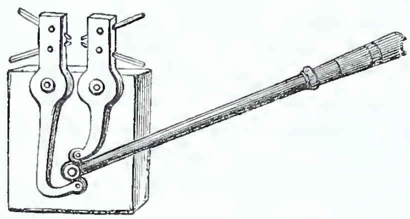

442. ARRANGEMENT OF DIES FOR SCREW-CUTTING.


443. ARRANGEMENT OF LATHE FOR SCREW-CUTTING.

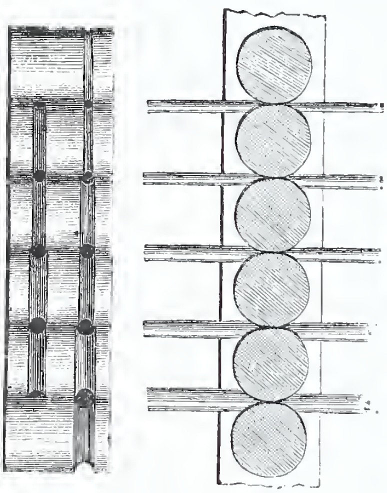

444. SCREW-CUTTING MACHINE.

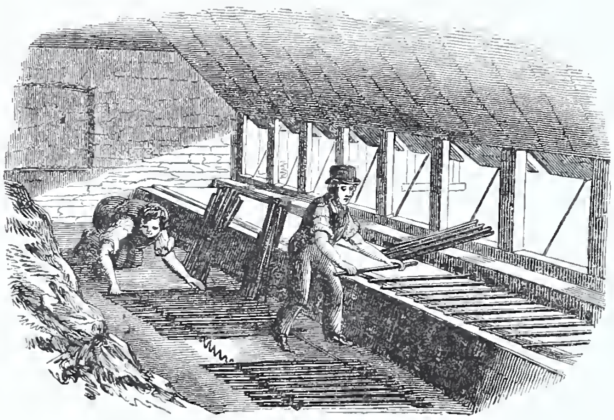

445. FORMS OF WORM.

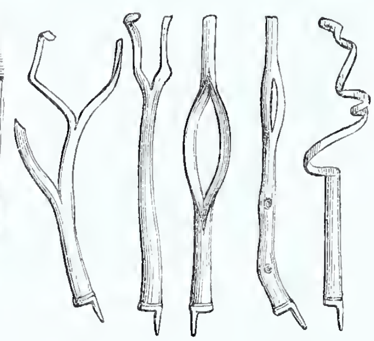

446. CAST BULLETS.


447. SCREW CUTTERS.

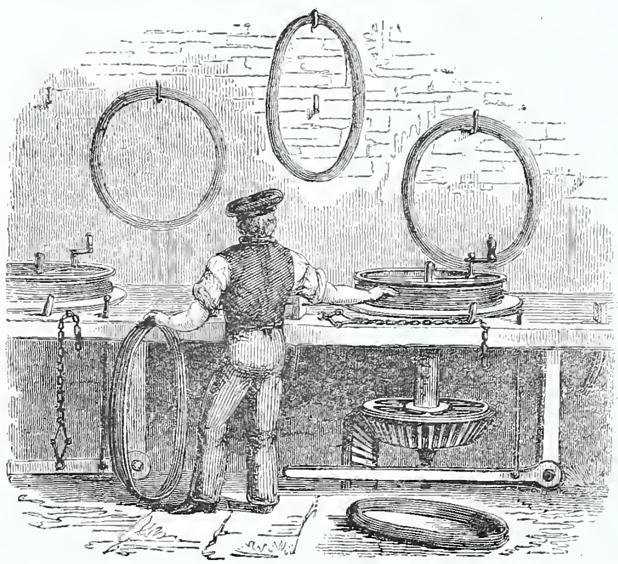

448. TWISTED BARREL.


449. STEEL ROLLERS.


450. INTERIOR OF PROOF-HOUSE.

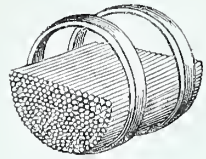

451. GUN-BARRELS BURST IN PROVING.


452. CUTTING THE NICK.


453. WIRE-DRAWING.

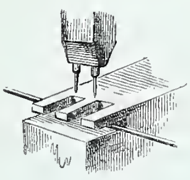

454. CUTTING THE WORM.

455. CUTTING THE WIRE INTO LENGTHS.

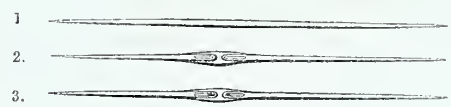


456. STRAIGHTENING RINGS

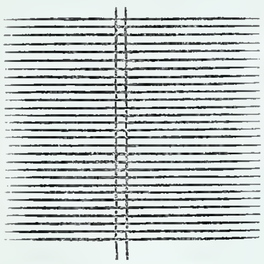
457. STRAIGHTENING THE WIRE.



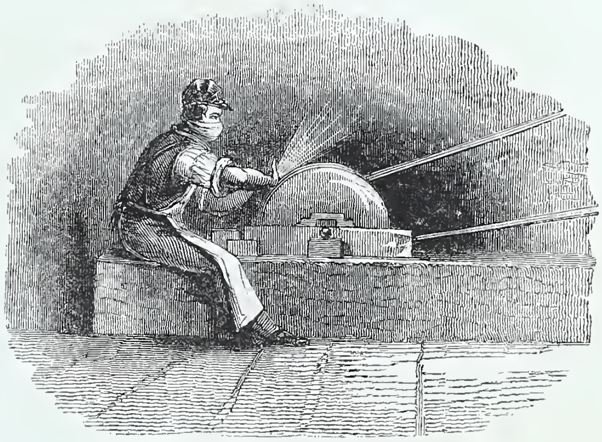
459. EYEING.



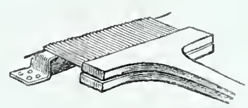
461. COMMENCEMENT OF EYEING.



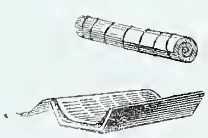
460. SPITTED LENGTHS.



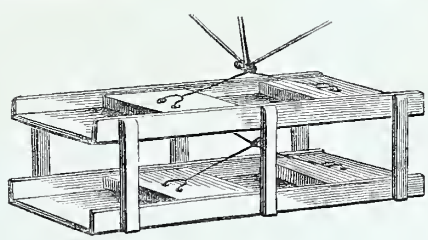
458. POINTING THE NEEDLES BY DRY GRINDING.



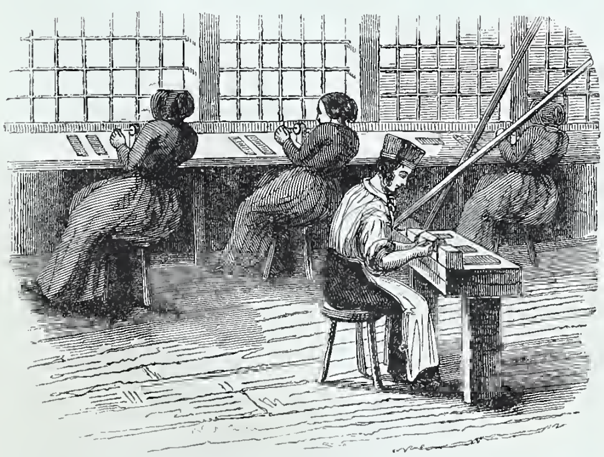
462. HEADING.



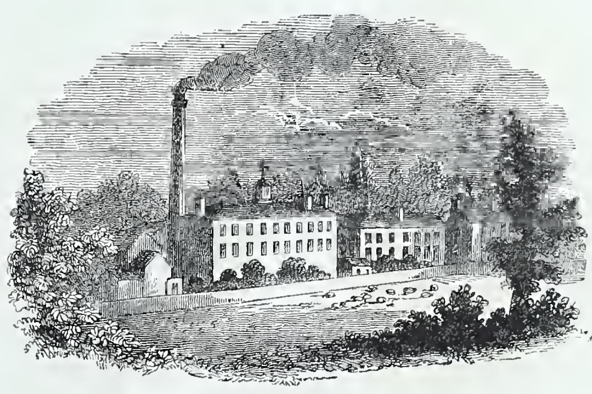
463. MAKING UP BUNDLE.



464. SCOURING MACHINE.



465. DRILLING AND POLISHING.



466. THE BRITISH NEEDLE-MILLS, REDDITCH.

as it is wanted. Pieces of the proper length are cut off; one end of each is struck up to form the head, and the blanks thus produced are turned out into a box. The blanks are placed separately in a lathe, and the heads and necks are properly shaped by turning. Next, the notch or nick in the head of the screw is cut by a circular saw (fig. 452). A woman puts each blank into a metal clasp, and by means of a lever raises it to the cutter; then opens the clasp, when the blank falls out, and she inserts another in its place with great rapidity. The next operation is worming, or cutting the thread, which is also done in a lathe; the nick just formed assisting in holding it steadily therein. Fig. 443 shows the arrangement of the lathe:—a steel spindle revolves in a lathe by the motion of a strap passing round the fast-pulley *f*; *l* being a loose pulley, to which the strap is shifted when it is required to stop the machine. At *i* is an iron box for holding the regulating screw (*p*), which is an exact pattern of the thread of the screw to be cut. The blank *s* is fixed in an iron cheek (*b*), and is held by the chisel spike of a hasp, entering the nick of the blank. The cutters are arranged in the frames at *c*, and are shown on a larger scale in fig. 447. The frames move on joint pins, so that by the action of a lever the cutters can be made to act on the shank of the blank with any required amount of pressure. There is also a lever, which causes certain directing points resembling the cutters to close upon the regulating screw *p*; and the two levers being connected by a horizontal bar, the cutters and the directors can be applied at the same moment; so that while the inclination of the thread is determined by the pattern screw, its shape is given by the form and position of the cutters fig. 447. *Gimlet-pointed screws* are cut by means of dies (fig. 442) instead of cutters. The dies are opened and shut by a right and left handed screw; and as the dies regulate the size of the thread, a pattern screw is not required. The form of the worm is f importance to the efficiency of the screw, as will be evident by comparing the new with the old form in fig. 445. The first figure represents the screw, the second the mould made by it in wood, while the third is a section of the common form of screw, in which the worm is shallow and imperfect.

The large iron screws, used in vices, presses, &c., are cut by the *screw-cutting machine* (fig. 444), which consists of a slide rest, in which the tool-holder is slid along by means of the guide-screw S, which receives its motion from the work in the lathe by means of the wheels W W. As the tool-holder slides along, it must evidently leave a spiral or screw in the work X; and according to the respective diameters of the wheels W W, the screw on X will be more or less fine in what is called the *pitch* of the thread, according to the proportions of the respective diameters of the wheels W W.

Gun-barrels.—Gun-barrels are made in large numbers at Birmingham. The iron is fagoted, hammered, flattened out between rollers, and clipped with shears into a plate or *skelp* of the proper size for a gun-barrel: this is then moulded into shape over an iron maundril, so as to form a compact tube of iron. A strike among the skelp-welders, some years ago, led to a method of welding gun-barrels by rollers. The plan consisted in turning a bar of iron, about a foot long, into the form of a cylinder, with the edges a little overlapping. This was raised to a welding heat; and a cylinder of iron being placed in it, it was passed quickly between a couple of rollers: the welding was thus performed with a single heating, and the remainder of the elongation required to bring it to the proper length was performed in a similar manner, but at a lower temperature.

Barrels for fowling-pieces are known as *stub*, *stub-twist*, *wire twist*, *Damascus-twist*, *stub-Damascus*, and some others. Stub iron is formed from old horse-shoe nails called *stubs*, a form of iron which owes many of its good qualities to its repeated workings. The stubs are packed closely together, bound by means of an iron hoop into a ball, raised to a welding heat, united by hammering, and drawn out into bars of convenient length; or the stubs may be mixed with a portion of steel and be puddled, and after welding into a long square block, may be drawn out by a tilt hammer (fig. 395) into rods of the proper size. Stub-barrels are also formed from scrap iron, which consists of the cuttings and waste of various manufactories. This is sorted, and iron of various qualities is prepared from it, such as *wire-twist*, *Damascus-twist*, *stub-twist*, &c. For twisted barrels, the iron is drawn out into ribbons, and these are twisted, while red-hot, over an iron rod fig. 448: the welding of the edges being completed by *jumping*, that is, striking the spiral forcibly on the ground, and also by hammering.

After the barrel has been forged, it is bored: the exterior is turned in a lathe; and the barrel, having been made equal and quite correct in every part, is tapped or screwed at the breach end, and the plug is fitted. The barrel is next proved by giving it a charge of gunpowder three or four times greater than it will afterwards have to bear, and a bullet is also added. The bullets are cast by pouring lead into a long mould, which, when opened, produces them in the form shown in fig. 446; but they are separated from the pipe and stem with a pair of nippers with cutting edges, adapted to the surface of the bullet. The barrels being thus prepared, are arranged on frames in a low shed, fig. 450, to the number of about 130, in two rows, one above the other. The shutters being closed, the barrels are fired by means of a train; and the bullets are received into a mass of sand placed against a dead wall. The barrels that pass well through this ordeal, are stamped with the mark of the Birmingham Proof-House; but those which are burst are of course returned as useless. Fig. 451 represents a number of specimens of barrels burst in proving.

Wire-drawing.—The process of drawing out a length of wire from a short thick rod is a gradual one. The rods are reduced in size by passing them repeatedly through rollers, one arrangement for which is shown in fig. 449; in which the rod of iron or of steel, having passed between the first and second rollers from the bottom, the end is caught by a man on the other side, with a pair of tongs, and pushed back between the second and third rollers: it is then passed between the third and fourth, and is further reduced between the fifth and sixth. The rods are made up in coils for the wire-drawer, who removes scales of rust from them by putting them into a revolving cylinder with coarse gravel and water. The rod is then forcibly dragged through a hole in a piece of hard steel called a draw-plate; and as this hole is a little smaller than the wire, the latter must yield and become extended in length: this lengthened wire is again passed through a hole smaller than itself, whereby it is again drawn out, and so on for ten, twenty, or thirty holes, all gradually diminishing in diameter until the proper size is obtained. Fig. 453 represents the factory arrangement for wire-drawing. The draw-plate is fixed in a bench, and by the side of it is a short cylinder or drawing-block, the rotation of which draws the wire through the plate, and winds it on the rim of the block. Motion is given to this block by means of a horizontal shaft, containing a mitre or bevel wheel, which drives the upright shaft, containing the block. Each block can be stopped in a moment by pressing a lever with the foot, whereby the block is lifted off its upright axis. After the rod has been drawn out a few times, the metal is so hard, by the forcible compression of its fibres, as to require softening before the drawing can be continued. The wire is therefore made up in coils, placed in cylindrical boxes, raised to a red heat, and allowed to cool gradually. This operation may have to be repeated several times during the drawing; and after each softening, the wire must be cleansed by being pickled in dilute sulphuric acid. It is also usual to place the coil at the draw-bench in a tub of starch water, or stale beer grounds. This enables the wire to pass more easily through the draw-plate, and also has the effect of giving a clear bright colour to the wire.

Needles.—The manufacture of these small but most useful

articles includes a number of minute but interesting processes, and affords a good illustration of the valuable principle of the division of labour. That a large factory, such as that represented in fig. 466, should be devoted almost entirely to the production of needles may well excite surprise ; but there is more cause for admiration in the fact, that this picturesque Worcestershire village contains a number of needle factories ; that the whole population of the village is directly or indirectly concerned in the production of needles ; that many of the processes are conducted in the cottages of the villagers, and further, that this absorption of the faculties of a whole village is not confined to Redditch, but applies also to Feckenham, Bexley, Studley, Coughton, Alcester, Astwood Bank, Crabb's Cross, and some other villages, all of which lie near together. Some years ago, when the writer visited Redditch, he was informed that the weekly production of needles in that village amounted to 70,000,000. The increasing population of Great Britain, and the fact, as we hope it is, that very few females in the land are unskilled in the use of the needle ; the demands of our colonies and of foreign countries for British needles, may well entitle us to believe the statement that, at the present time, upwards of 10,000 persons are directly concerned in the manufacture of these tiny articles.

The wire for good needles is not *mill-drawn*, as described above, because by such means the surface of the wire is not sufficiently smooth, nor the gauge or thickness of the wire sufficiently regular ; but the wire is *hand-drawn*, in which case the man attends to one drum instead of to several drums ; and should the wire *rip* or *tear*, the drawer can feel it, and remove the damaged wire. Besides this, after each softening, the use of sulphuric acid is avoided ; the scale being removed by means of rubbers covered with emery and oil.

The first process in needle-making is to cut the wire into lengths by means of shears, fig. 455 ; each length being sufficient for the making of two needles. In the needles known as No. 6, each piece is about three inches long, and as many as 30,000 pieces form one batch. The lengths thus produced partake of the bend of the coils from which they were cut. The second process is to straighten the wires ; for which purpose many thousand lengths are placed within a couple of rings, fig. 456, and are thus conveyed to a furnace, where they are heated to redness and then allowed to cool slowly. This softens the wires and admits of their being straightened by mutual friction, for which purpose a tool called a *smooth file* is placed between the two rings (fig. 457), and rubbed briskly backwards and forwards, when the motion of the lengths upon each other effectually straightens them.

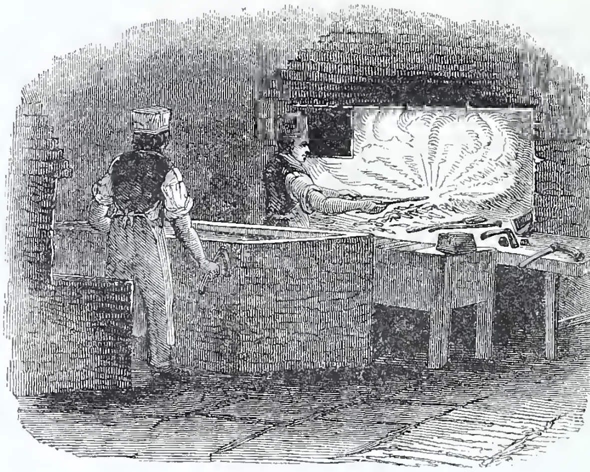
The third process is pointing, or grinding the ends of the wires on a grit stone (fig. 458). Several thousand wires can be pointed at both ends in an hour. A stream of sparks accompanies the contact of the wires and the stone, and minute particles of grit and steel fill the air of the room, and, entering the workman's lungs, produce a disease called the "grinder's asthma." The only effectual remedy for this is ventilation, or so to box in the stone, and connect it with a channel passing out into the open air, and so to rarefy the air in this channel by means of a revolving fan, that the air of the workshop shall always tend to move in a current, and blow downwards upon the stone so as to convey the metallic and stony dust into the shaft. The stones for the dry grinding of cutlery (fig. 479) are arranged on this plan with wonderful benefit to the health of the workmen.

The next process is to flatten out the centre of each wire, by means of a pair of dies and a stamp, so as to form the shape of two eyes, the ring of the eye being less indented than the other portion. Fig. 461 will show the progress of eyeing. No. 1 is the wire pointed at both ends ; No. 2 represents the groove or *gutter*, which is useful to guide the thread in threading a needle. A spot is also indented where the eye is intended to be. The eyes are next pierced through by means of a couple of steel points (fig. 459), when the wire is in the condition of No. 3, fig. 461. If it were attempted to flatten out the wire and perforate it at one operation, the metal would be torn and otherwise injured. The next operation is to remove the bur or projecting line of metal on each side of the eyes. For the sake of expedition, a number of lengths are spitted on two wires, fig. 460, and the burs are removed by means of a flat file. The lengths are next separated into two portions, by bending the soft wire backwards and forwards between the two spits. The points of each row of needles are then grasped in a kind of hand-vice or clam, as shown in fig. 462 ; and the heads, being placed on a raised piece of metal, are filed into shape. The needles are now said to be *headed* or *made ;* not that they are by any means finished, but they are complete so far as regards the length, the point, the eye, and the head.

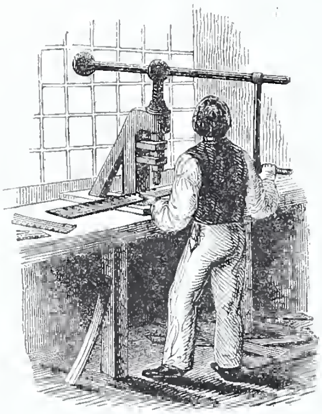
The foregoing details include the *soft work*, as it is called. Preparatory to the bright work, the needles go to the *soft-straightener*, who rolls them upon a flat steel plate with the convex face of a smooth steel file. The next process is *hardening*, for which purpose the needles are raised to a red heat and are suddenly cooled by being quenched in cold water or oil. This makes them hard and brittle. Some of their hardness is removed by *tempering* on a hot iron plate ; and when a blue film begins to form upon their surface, they are then said to be of the proper temper. The action of heat has been to distort the needles more or less ; and the next process is *hard* or *hammer-straightening*, in which each needle is tapped with a small hammer upon an anvil. The anvil is a smooth plate of steel, upon which the needles are rolled with the finger ; and such as are not quite straight are immediately detected and corrected. This work is commonly done by women in their own cottages. Then comes the operation of *scouring* or *cleaning*. From 40,000 to 50,000 needles are made up in a bundle, by first placing a piece of canvas in a tray, fig. 463, and then arranging the needles in heaps in the direction of their length. Emery, oil, and soft soap are sprinkled on the needles ; when they are rolled up in the canvas, and formed into the cylinder shown in fig. 463, by tying with string. A couple of such rolls are placed in the *scouring-machine*, fig. 464, which consists of weighted slabs or rubbers, which roll the bundles of needles backwards and forwards ; and this friction is kept up for fifty or sixty hours, the effect of which is to make the needles rub over and over each other ; and this, with the assistance of the oil, emery, &c., produces that smooth bright surface which is essential to the useful action of a needle. The bundles of needles wear out under the friction ; so that after about eight hours' rubbing they are unpacked, the needles are washed in soap and water, and packed up again with a mixture of putty-powder and oil. They are then placed in the scouring-machine for another eight hours ; and this process is repeated, for the best needles, five or six times. There is no better method of polishing than this, although it leads to a considerable amount of breakage.

The needles are next passed into the *bright-shop*, where they are collected in trays, and arranged with the points all the same way : this is done by placing the needles in heaps, and pressing the ends against the flat of the hand by means of the fore-finger, which is wrapped up in rag ; such of the needles as have their points towards the rag enter it, and can be drawn out and turned over without any difficulty ; and in this way the 40,000 needles can be easily and quickly arranged in trays, with the points all in one direction. The eyes are now *drilled*, in order to get rid of the rough or jagged surface of the interior edges of the eye ; but preparatory to this, the metal above the eye requires to be softened, which is done by placing a number of needles on a steel slab with their eyes projecting over the edge. A hot plate is then brought under the eyes, but so as not to touch them ; when in less than a minute a film of a dark blue oxide covers the metal about the eyes, and indicates the proper temper for drilling. The drills are small three-sided tools, revolving horizontally with great speed, arranged at a well-lighted bench (fig. 465). A young woman with keen eye and steady hand, taking a few needles by the points, spreads them out like a fan, and brings the eye of each up to the drill ; and by a motion of the finger and thumb presents

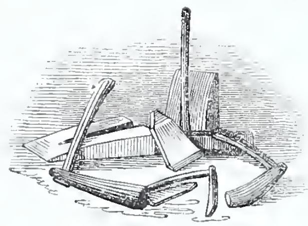
467. CUTTING FILES.



468. HARDENING FILES.

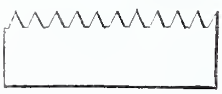


469. CUTTING THE TEETH.



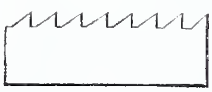
470. FILE CUTTER'S TOOLS.

471. SETTING THE TEETH.

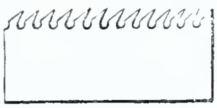


472. CROSS CUTTING SAW.

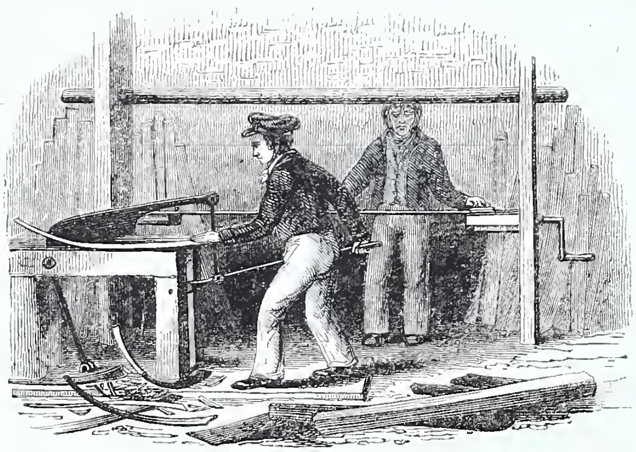
473. HAND-SAW.



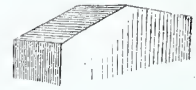
474 MILL-SAW.



475. PIT-SAW.



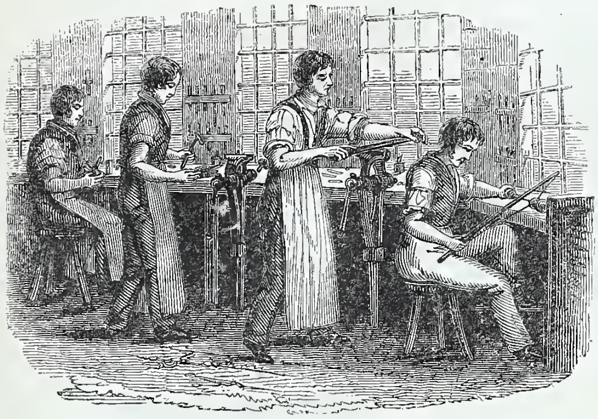
476 CUTTING OUT SAW BLADES.



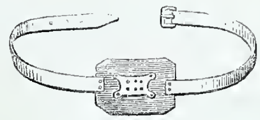
477. SAW-SETTER'S ANVIL.

478. FORGING TABLE-KNIVES.

479 GRINDING CUTLERY.

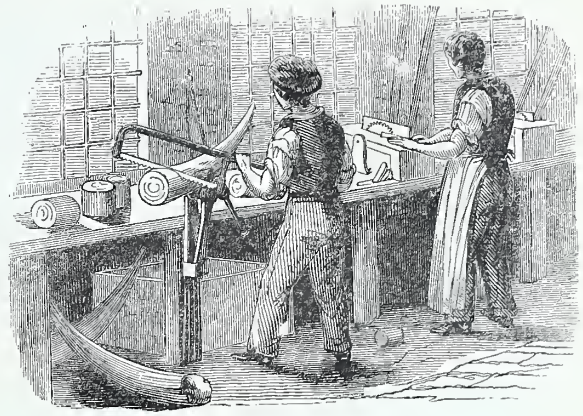


480. Cutlery Workshop.



482. Breastplate.

483. Boring Stick.



481. Preparing Ivory Handles.

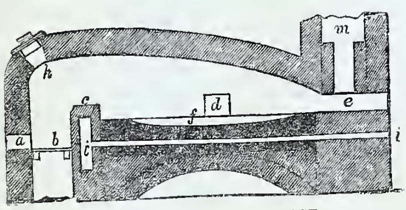
484. Holder.

485. Holder.

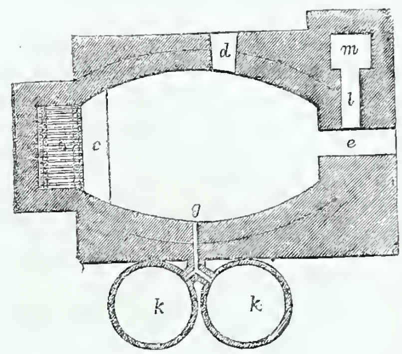
486. Fork Mood.

487. Drill.

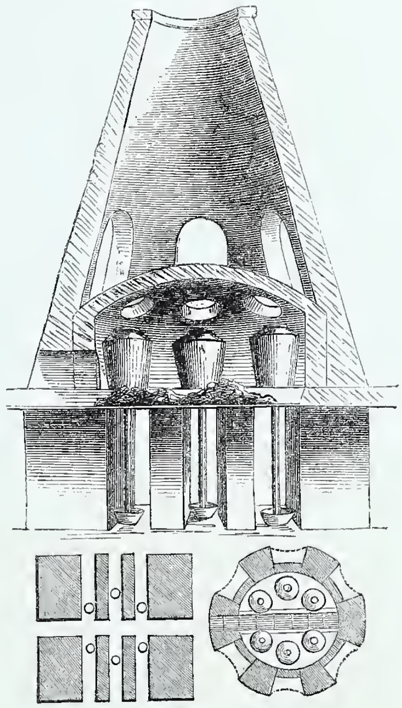
488. Double Drill.



489. Tin Smelting Furnace.

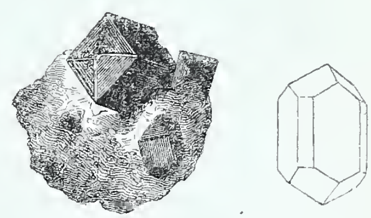


490. Plan of Tin Smelting Furnace.

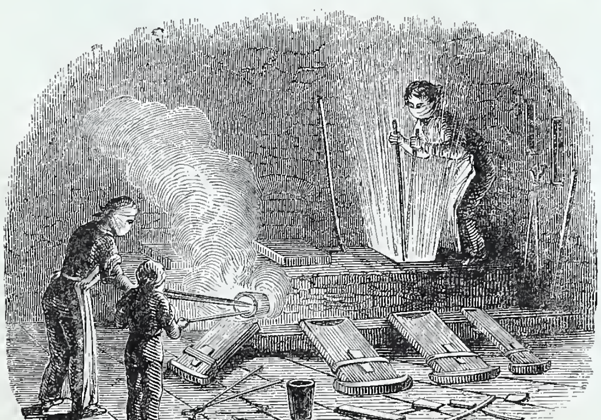


491. Zinc Furnace.

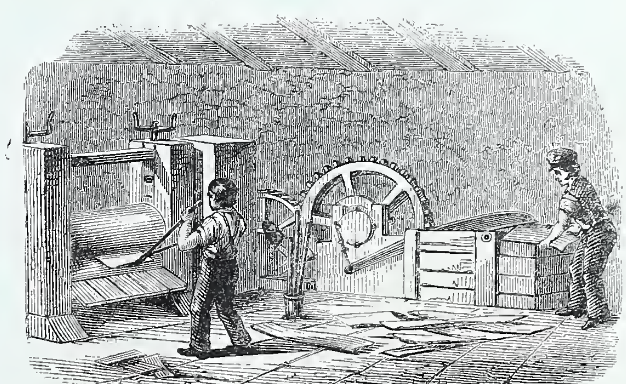
492. Filling Crucibles (*Brass*).



493. Tin Crystals.



494. Casting Brass.



495. Rolling Copper.

either side at pleasure. The eye is first counter-sunk, by which means the sharp edge which connects the eye with the gutter is rounded. The drill is then passed round the rest of the edge of the eye, the ragged parts are removed, and that kind of form is given to the eye which may be noticed in the loops of a small pair of scissors. The points of the needles are next finished on a small stone, and then polished with polishing paste on buff wheels. Lastly, the needles are counted into quarter hundreds, folded up in blue papers, and labelled. If intended for exportation, the bundles are made up into square packets, and these are packed in cases of tinned iron. In the course of the manufacture the needles are repeatedly examined to see that the work is properly done, and to weed out defective specimens.

Files.—Files are almost as numerous as the work which they perform is varied. They may vary in length from three quarters of an inch to two or three feet and upwards ; and they are distinguished as taper, blunt, and parallel ; the first kind being most numerous: those of the second kind terminate in a square or blunt end. Both these kinds swell out towards the middle, so that the sides are somewhat arched or convex ; and even those files which are called parallel are a little fuller in the middle. Files are also known as Sheffield-made and Lancashire-made ; the latter being produced at Warrington, and consisting mostly of the finer varieties, such as are used by watch and clock makers. Files may also differ in the forms and sizes of the teeth. In *double-cut* files, two series of straight chisel-cuts are made to cross each other, so as to raise on the surface of the file an immense number of points or teeth. In *single-cut* files a number of ridges are raised square across the file, by means of one series of straight chisel-cuts. Such files are called *floats*, the file properly so called being always double cut. A *rasp* is formed by dotting over the surface of the steel with separate teeth, by means of a pointed chisel or punch.

Files are made of steel ; and the teeth are cut with a chisel, shown in fig. 470, which is struck with a peculiarly-shaped hammer, also represented ; the file-cutters at work being shown in fig. 467. The blank is held on the anvil by a leather strap passing over each end of the blank and under the feet of the workman ; and, to prevent injury to the metal, the blank is supported by a block of lead and tin. The blow of the hammer upon the chisel throws up a trifling ridge or bur ; and after each blow the man immediately replaces the chisel on the blank, and slides it away from him until it encounters the ridge previously thrown up ; this arrests the chisel, and guides the man in making his blow. In this way from sixty to eighty cuts may be made in a minute ; the first course of cuts being somewhat deeper than the second. Round files are cut in a similar manner ; rows of short cuts being made from the bottom to the top of the file ; and these cuts, uniting at their extremities, form a series of complete lines round the cylinder.

The metal is in a soft state while the teeth are being cut. After the cutting, the files are hardened : they are first drawn through beer-grounds, yeast, or some other adhesive fluid, and then through a mixture of common salt and charred cow's hoof ; the object being to protect the teeth from the action of the fire. The files are raised gradually to a dull red heat, and suddenly cooled by plunging them into a cistern of water (fig. 468). They are then scrubbed, dried, smeared with a mixture of olive oil and turpentine, and tested ; when they are ready for the market.

Saws.—Saws form a numerous class of tools. The size and form of teeth, the dimensions of the blade, and the method of mounting vary with the uses to which the saw is to be applied. In an ordinary *mill-saw* (fig. 474), the teeth are right-angle triangles ; in the *pit-saw* (fig. 475), they consist of a succession of demi-lunettes, this being the keenest form for cutting. Fig. 472 is the *cross-cutting* saw, with spaces at the bottom to prevent the teeth from being choked up with sawdust. In the carpenter's *hand-saw* (fig. 473), as in most other common saws, the spaces at the bottom of the toothing are omitted.

The best material for saws is cast steel, rolled out into plates of uniform thickness, and cut to the required size by means of stout shears, arranged as in fig. 476. The edges of the pieces being ground true, the teeth are cut at a fly-press (fig. 469) by means of a steel die-cutter, working vertically in a steel die. When one tooth is cut, the man shifts the notch into an upright piece of steel, which fits it exactly, and then cuts out another notch, which in its turn is moved into a steel die, when a third notch is cut out ; the metal between every two notches forming a single tooth, while the guide serves to keep all the teeth equidistant. After the teeth have been cut, the blade is put into a vice, and the wiry edges left by the punch are filed down, and the teeth finished. The blade is next hardened by being raised to a cherry-red heat, and plunged edgeways into a bath of cold oil, grease, pitch, &c., according to the fancy of the maker. The blade is now very hard and brittle, and is tempered by being stretched in an iron frame, and heated until the unctuous matter on the surface takes fire ; the blade is then removed from the fire, and left to cool. *Back-saws*, or those which are afterwards furnished with a brass or iron back to keep them straight, are made in lengths of several feet, and are afterwards cut up. Small saws are not put into frames during the tempering, but are held in the furnace by means of tongs until the unctuous matter begins to "blaze off," as the workman calls it. *Planishing* or *smithing* is the next operation, in which the saw is placed on a small anvil of polished steel, and assiduously hammered, but with that care and judgment which experience gives, so as to make the metal of equal density and elasticity throughout. The blade is next ground on large wheels or grindstones ; after which it is again planished, and is next held over a coke fire until a slight degree of oxidation, indicated by a faint straw colour, is produced. This restores the elasticity, which was injured by the grinding. The blade is next passed lightly over the grindstone to remove the marks of the hammer ; it is then smoothed upon a hard, smooth stone, and is lastly polished on a wheel, covered with buff leather and smeared with a composition of emery and suet. The blade is again planished or *blocked*, after which it is cleaned off with emery, so as to produce an even white tint and a level appearance. The saw is not even yet finished ; for the teeth require to be *set*, to prevent them from becoming choked up with saw-dust. This *setting* consists in bending every alternate tooth a little on one side, and the intermediate teeth a little on the other side. For this purpose the setter places the teeth on the ridge of a small anvil, fig. 477, and with a light hammer runs along the teeth, striking every other tooth so as to bend it a little ; and then, turning the saw over, strikes the intermediate teeth. This delicate operation (fig. 471) is performed with great rapidity and precision ; it seems scarcely possible that the intended effect should be produced without breaking off some of the teeth, or failing to hit the right tooth at the right moment. The saw is next placed in a vice, and the teeth are filed up ; it is again held over the fire, and the film of oxide formed upon it is afterwards washed off with a weak acid : and at length the saw is ready for handling. Beech is the wood usually selected for the purpose.

Cutlery.—The various articles which are included under the term cutlery, are or ought to be manufactured of steel. In some cases, however, the working parts of the tool or instrument are alone made of that metal. Cast steel can be readily welded to iron ; so that the cutting parts of chisels, plane-irons, &c., may be formed of it, and the rest of the tool of the inferior metal. Where not much hardness is required, as in table-knives, scythes, plane-irons, &c., shear-steel is used ; but articles requiring a fine polish, such as razors, penknives, scissors, &c., ought to be made of cast steel.

In the production of a table-knife, the blade is first roughly forged from a bar of shear steel (fig. 478), and is then cut off and welded to the end of a rod of iron, about half an inch square, and a portion of this is cut off, sufficient to form the *bolster*, or shoulder, and the *tang*. The proper size and shape are given to

the bolster by introducing that part of the metal into a die on the anvil: a hollow mould or *swage* is then put on it, and a few smart blows are given to it with a hammer. The blade is next heated, and properly finished on the anvil: this is called *smithing* the blade: the maker's mark is stamped on it, and the blade is hardened by raising it to a red heat and plunging it into cold water: it is tempered to a blue colour, and is then sent to the grinder. The grinding and polishing of cutlery are carried on at Sheffield, which is the seat of the trade, mostly in buildings called *wheels* or mills; each mill being divided into a number of separate rooms called *hulls* (fig. 479). Most small articles are ground upon a dry stone; this produces those fatal consequences to the workmen, which were alluded to when describing the pointing of needles. The proper ventilation of the stones, however, has done much to remove or mitigate the evil; and the dust collected in a trough of water at the extremity of the ventilating shaft is large in quantity, and seems to have the density of metal. The fan which rarefies the air in the ventilating shaft, is made to revolve by the same means which gives motion to the grindstones; so that the ventilating arrangements, not being subject to the will or caprice of the men, are likely to be efficient.

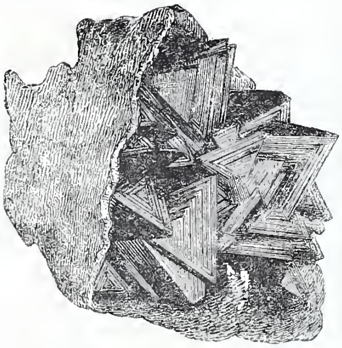
The proper shape is given to the blade by grinding; and as the concavity in such articles as razor-blades depends on the size of the stone, it is important to select the proper size. A stone, four inches in diameter, will give a corresponding concavity to the blade, or a curve of two inches radius; and such a curve will evidently yield a keener edge than can be produced from a six, eight, or twelve-inch stone; because the smaller the diameter, the more convex is the stone, and the more concave will be the blade that is ground upon it. The friction of the blade against the stone produces great heat, so that some contrivance is necessary to protect the grinder's hands. Table-knives are fitted in a wooden case (fig. 484); penknives in a holder (fig. 485). After grinding, the blades are glazed on wheels of wood, or wooden wheels faced with leather, or with an alloy of lead and tin: they are then polished on buffs, dressed with crocus of iron.

There is a large consumption of ivory for the handling of knives, forks, &c. The best method of attaching handles to knives and forks is to fasten a flat piece of ivory upon each side of a flat piece of iron continued from the blade: the next best method is to drill a hole through the length of the handle, to pass the prong of the knife through the hole, and rivet it at the opposite end: this is called *through-tang*. The most common method is to pass the prong about half-way into the handle, and to secure it with melted resin mixed with whitening. Such a handle, however, will become loose when the knife is put into hot water. *Balance-handles* are made by perforating the haft deeper than usual, and dropping in a small piece of lead; the knife then rests upon the handle and the shoulder, and the blade does not come in contact with the table-cloth. In preparing the handles, the tusks, whether of the elephant or of the walrus, are cut up first with a small frame saw, and then with a circular saw (fig. 481). Stag-horn handles are softened by boiling to bring them to the proper shape; cow-horn is brought to the proper shape by means of iron moulds, assisted by heat. Various other materials are used for handles, such as tortoise-shell, mother-of-pearl, fancy woods, stamped gold and silver, &c.

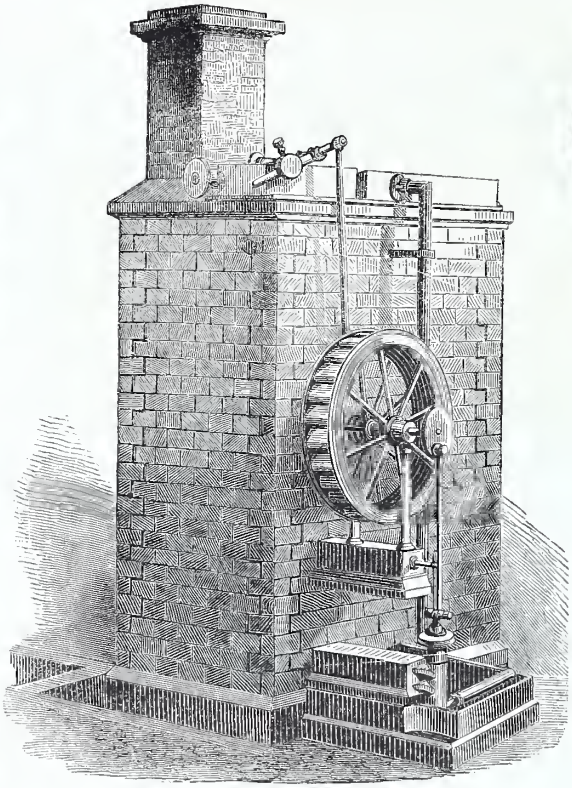
The processes of the cutler's workshop (fig. 480) are numerous and minute, even for a common article of cutlery. A common penknife with three blades has to pass through the workman's hands at least one hundred times. When the blades, spring, and *scales* (or thin metal supports to the handle) are bored with the proper holes, they are pinned together, to see that the parts fit and work well: they are then riveted with bits of wire, with a hammer on a small anvil. The horn, ivory, or shell sides are filed smooth, scraped, and polished twice on the buff; first with Trent sand, and then with oil and rotten-stone. The backs of the springs are glazed and then polished with a steel burnisher: holes are bored with a steel drill, passed through a wooden cylinder, fig. 487. Motion is given to this by means of a *boring-stick*, fig. 483, the thong of which is twisted round the cylinder of the drill; the short end of which is held against a breast-plate, fig. 482, which is strapped round the workman's body. A *double-drill*, fig. 488, is used for hollowing out the cavity for the shield or plate of silver let into one side of the handle. This drill consists of two elastic steel blades, sharp at one end. A plate of steel, perforated according to the required shape of the shield, is placed on the handle, and within this perforation the two ends of the drill are held, and made to revolve by means of the boring-stick. The tendency of the springs to coil round each other by the motion, and to fly asunder by their elasticity, causes them to describe a number of small circular arcs; and as the man constantly moves these points over every part of the circumscribed space, the cavity is soon hollowed out: the plate or shield is then driven in, and is held in its place by two pins projecting from the under-surface.

XXVII.—TIN, ZINC, BRASS, AND COPPER.

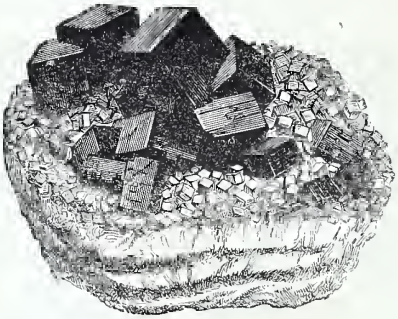
We have already described the mechanical operations by which the ores of tin are separated from their stony matrix, and prepared for the smelter. The furnace in which the prepared ores are reduced is represented in vertical section fig. 489, and in plan fig. 490. *a* is the *fire-door*, through which the fuel is placed upon the grate *b*; *c* is called a *fire-bridge*; at *d* is a door for the introduction of the ore; and at *e* is another door, through which the ore is worked upon the hearth *f*; *g* is the *stoke-hole*; *h* is a hole which is occasionally opened to admit a draught of air for carrying the fumes up the chimney, *m*; *l* is a flue; at *i i* are channels for admitting cold air under the fire-bridge and hearth, to protect them from the heat; *k k* are basins into which the melted metal is drawn off. The ore is mixed with small coal, and a flux of slaked lime; and it is damped with water to prevent the draught from sweeping away the finer portions. When the furnace is charged, the doors are closed and *luted*, or stopped with clay, and the heat is gradually raised. In the course of six or eight hours, the reduction of the oxide is completed; the door of the furnace is removed, and the melted mass is worked up to complete the separation of the scoriæ. About three-fourths of the scoriæ are rejected as refuse; a second portion contains about five per cent. of tin, and is sent to the stamping mill; while that last removed contains much tin, and is set aside for smelting over again. The channel leading to the basins *k k* is then opened, and from the basins the tin is lifted in iron ladles, and poured into iron moulds. These blocks



496. BLENDE, OR BLACK JACK.



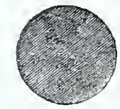
498. FUME CONDENSER.



497. GALENA.

500. SHELL.

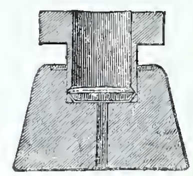
501. COLLET.



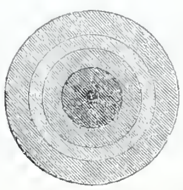
502 COVERING.

503. SHANK.

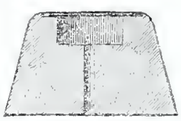
499. STAMPING FORKS.



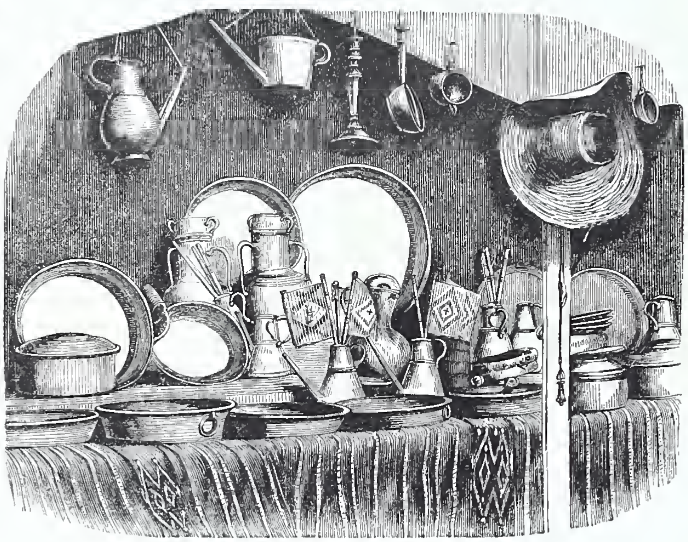
506. HOLLOW TOOL AND MOULD.



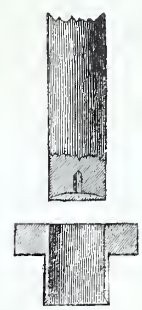
504 PADDING.



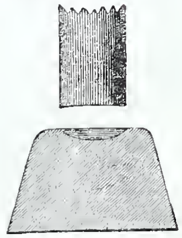
505. MOULD.



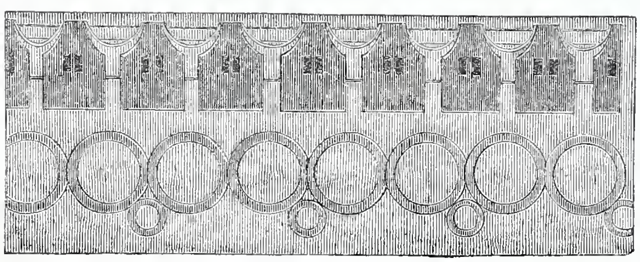
509. HARDWARE FROM TUNIS.



507. HOLLOW TOOL.

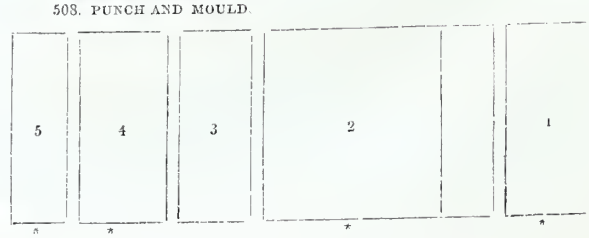


508. PUNCH AND MOULD.



510. MELTING-POTS.

511. STAMPED FORK.

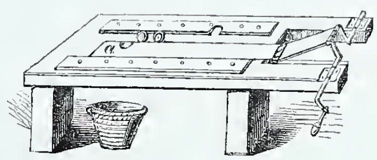


512. ARRANGEMENT OF POTS FOR TINNING.

514. CLEANING.

513. CUTTING OUT BLANKS

516 SHANKING

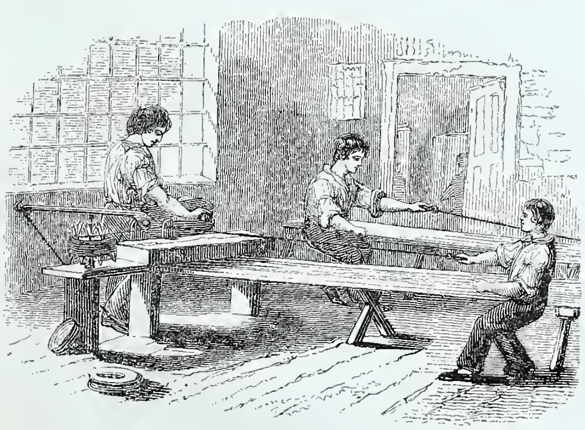


515. ROUNDING THE EDGES

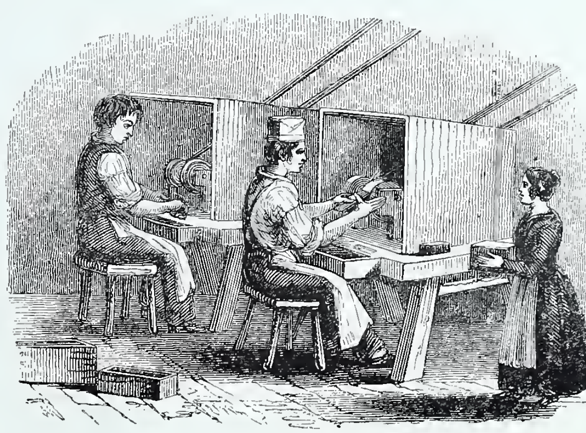
518. BURNISHING.

517 DRYING OFF.

520. FIXING THE HEADS.



519. STRAIGHTENING THE WIRE.



521. POINTING.

of tin are further purified by *refining*, which is done by arranging the blocks in a furnace near the bridge, and raising them to a moderate heat: the tin melts, and flows away into the refining basin, leaving most of the impurities behind. Other blocks of tin are arranged on the remains of the first; and when about five tons of melted metal have been collected, billets of green wood are plunged into it, the effect of which is to give the tin the appearance of boiling: a kind of froth rises to the surface, but the most impure and heaviest portions fall to the bottom. The froth is skimmed off, and the tin is left to settle: it separates into different portions, of which the top stratum is the most pure, the bottom the most impure, and the middle of average purity. The tin is ladled into iron moulds, forming blocks of about three cwt. each, known as *block tin*. The tin of the first stratum is called *refined tin*, and is chiefly used in the manufacture of tin plate.

Zinc being volatile at a high temperature, its ores are distilled in crucibles or pots, six or eight in number, contained in a cupola furnace, fig. 491, arranged somewhat like the pots of a glass furnace, fig. 276. In the bottom of each pot is a hole which is closed with a wooden plug. The charge for each pot, consisting of six parts calamine and one part coal, is put in from above, through an orifice in the lid of the pot, which is left open after the firing, until the bluish colour of the flame shows that distillation has begun. The hole is then covered with a fire-tile. The sole of the hearth on which each pot stands is perforated below: when the fire has heated the pots and consumed the wooden plugs, the end of a long sheet-iron pipe is put into each hole; the other end dipping into a vessel of water, which receives the condensed vapours of the zinc in drops and in a fine powder, mixed with a little oxide: this distilled zinc is melted in an iron vessel, and is cast into square bars or ingots.

The smelting of copper involves a long and complicated series of operations, which cannot be described here. The union of copper with zinc forms a number of useful alloys, depending on the proportions of the respective metals. Copper with about half its weight of zinc forms yellow brass. One pound of copper, with from one to one and a quarter ounces of zinc, forms *gilding-metal* for common jewellery. When the proportion of zinc is increased to three or four ounces, we get *Bath metal*, *Pinchbeck*, *Mannheim gold*, *Similor*, &c. With sixteen and a half ounces of zinc, we have *Mosaic gold*.

The furnace in which the copper and zinc are melted is a small wind-furnace, with the mouth standing eight or ten inches above the floor of the foundry. The crucibles are filled with the proper proportions of the two metals, well rammed in (fig. 492), and when, by proper attention to the temperature, which is maintained by means of coke, the alloy is supposed to be formed, the covering of the furnace is thrown off, and a man, striding over the opening, grasps the crucible between the jaws of a pair of tongs, and lifts it out of the furnace (fig. 494). After skimming, the crucible is seized with a pair of tongs, and the contents poured into an iron mould placed in a sloping direction, the stream being guided with an iron rod. During the process of pouring, the oxygen of the air seizes on a portion of the zinc and fills the air of the foundry with a dense cloud of white oxide. To prevent this from entering the lungs, the men tie a handkerchief over the mouth and nostrils. The effect of this white cloud seems to have prevented our artist from seeing clearly; since in fig. 494, the man who is filling the mould appears to have the tongs inside the crucible, instead of grasping them on the outside.

The cast plates are usually rolled into sheets, for which purpose they are cut into ribbons, which are passed cold through the rollers. The metal soon becomes too hard for lamination, and has to be softened in an annealing furnace. The ragged edges are cut off, and the sheets are then passed through the rollers two or more at a time; and as they become thinner, as many as eight plates may be rolled at once. Fig. 495 represents the rolling of copper.

Most of the lead of commerce is obtained from galena, or the native sulphuret (fig. 497). It occurs in veins in the primitive rocks, and is mixed with quartz, blende, pyrites, &c. Galena always contains a small portion of silver; sometimes as much as 120 ounces to the ton. The lead ore is separated to a great extent from earthy impurities by dressing, when it is mixed with lime, and heated to dull redness in a reverberatory furnace, through which a strong current of air is passing. A good deal of the sulphur burns off as sulphurous acid, and a portion of oxide of lead is formed: another portion of the sulphuret is converted into sulphate of lead. When the roasting, with much stirring, has been carried far enough, the furnace-doors are closed and the heat is raised. The oxide and the sulphate of lead react upon the undecomposed ore; a good deal of sulphurous acid escapes and metallic lead runs freely from the mass into cast-iron basins. The lead may be refined or *improved*, as it is called, by passing it through the furnace again. The escape of sulphurous acid, together with a portion of lead in the form of *fume*, causes much loss to the smelter and annoyance to the neighbourhood; destroying vegetation and poisoning the cattle. Many attempts have been made to condense this fume, the most successful of which is the apparatus used at the Duke of Buccleuch's works at the Wanlock-Lead Hills in Dumfriesshire. A portion of this apparatus is represented at fig. 498. It is divided within by a partition wall into two chambers; and the smoke from the various furnaces is brought by a suitable apparatus into these chambers, where it meets with descending showers of water, which condense it. We cannot explain this apparatus more distinctly without the use of sectional drawings; but we may state its success in the fact that, before it was erected, the heather was burnt up, vegetation destroyed animals, could not graze, nor birds feed near the spot; but that after its erection, the heather was seen in luxuriance close around the works; sheep were grazing within a stone's throw of the base of the chimney, and game was sheltering on all sides.

The best method of separating silver from lead depends on the fact, that if the melted lead be allowed to cool slowly, and be stirred during the process, a portion of the metal solidifies in the form of crystalline grains, which sink to the bottom: these grains consist of lead nearly free from silver, since the fusing point of the argentiferous alloy is lower than that of pure lead. In separating the silver, a number of cast-iron pots (fig. 510) are set in brickwork in a row, with a separate fire beneath each; about five tons of lead are melted in the middle pot, when the fire is withdrawn and the metal is briskly stirred: as the crystals of lead subside, they are removed by means of a perforated iron ladle to the next pot on the right hand. When about four-fifths of the lead is thus removed, the concentrated argentiferous alloy is ladled into the next pot on the left, and the empty pot receives a fresh charge. The straining off of the lead is thus continued from pot to pot, the argentiferous portion being continually passed on to the left, and the poorer portion to the right. The last pot on the left may thus become filled with lead, which may contain three ounces of silver to the ton; while the lead in the last pot on the right does not contain more than half an ounce of silver to the ton; the latter is cast into pigs for the market; but the former is passed through a *cupel* furnace, and being exposed at a high temperature to a current of air, the lead is converted into an oxide, which melts and flows off the convex surface of the melted metal; thus continually exposing a fresh surface of lead to the action of the air, until at length nothing is left but a cake of pure metallic silver.

Hardware.—The applications of the metals tin, copper, lead, and zinc, and their alloys, are so numerous that it would be impossible even to indicate them in this place. An immense number of articles are included under the general term *hardware*, the most primitive forms of which were collected in picturesque confusion in the Tunisian Court of the Great Exhibition, and are represented in a striking engraving, fig. 509. Birmingham is the centre of the

hardware trade of this country; and in its practice, we frequently notice the useful arts merging into the fine arts through the medium of the ornamental. From cabinet and general brass foundry, such as hinges, fastenings, bell-pulls, &c., we arrive at works in stamped brass, such as cornices, curtain-bands, finger-plates, where a certain amount of taste in design is required, until we come to gas-fittings, chandeliers, lamps, and candelabra, where taste admits of a higher development; and lastly, we have bronze figures, busts, and chimney ornaments, in which the taste, if not the genius, of the finished artist ought to prevail.

In copper, zinc, tin, pewter, &c., we have such common articles as kettles, coal-scuttles, saucepans, which are not remarkable for taste; and bronzed tea and coffee urns, &c., which, taking their place on a drawing-room table, ought at least to gratify the eye by their beauty of form. The same remark applies to teapots and articles in German silver. The term *hardware* also includes a number of objects, made of mixed materials, such as metallic buttons, Florentine, mother-of-pearl, bone buttons, &c. The metal zinc is commonly used for objects which, until recently, have been represented in tinned sheet iron. Articles in iron and steel are innumerable, including as they do stoves, grates, fenders and fire-irons, locks, hinges, and general ironmongery; hollow-ware, cast and wrought, tinned and enamelled; garden and other tools, nails and screws, steel toys and ornaments, steel pens, needles, fish-hooks, &c. &c.; but as the modes of production of articles in iron and steel have already engaged our attention, we may pass over these with one exception; and that is, the application of tin to the covering of sheet iron in the production of what is called tin-plate.

Tin-plate.—The best sheet iron is used for this purpose; and the first step towards tinning is to clean the plates, for which purpose they are bent in the middle, and placed on edge in a trough containing a solution of hydro-chloric acid. They are then conveyed to a furnace, heated to redness, and after cooling are straightened by being beaten on a cast-iron block. This gets rid of oxide: the plates are further smoothed by being passed between rollers, and are put one at a time into an acid mixture of bran and water. They are next pickled in a solution of sulphuric acid, assisted by a gentle heat, washed in cold water, and scoured with hemp and sand. The surfaces are now chemically clean, for without such precautions the tin would not adhere. The tin is melted in a cast-iron vessel, and is protected from the oxidizing influence of the air by a covering of tallow. By the side of the tin pot is a pot filled with grease only, for receiving the prepared plates, previous to tinning: they are taken out of this one by one, and plunged into the tin in a vertical position, to the number of 200 or 300, where they are left for an hour. After this they are taken out with tongs, and placed on an iron rack or grating, where a good deal of tin drains away from them; but a larger quantity is got rid of by the process of washing. An iron pot, called the *wash-pot*, is filled with melted tin, and by the side of it a grease-pot full of clean melted tallow. There is also a third pot called the *pan*, with a grating at the bottom for receiving the plates when taken out of the *grease-pot*. A fourth, called the *list-pot*, contains only a small quantity of melted tin. Fig. 512 shows the arrangement of all the pots. No. 1 is the tin-pot, in which the plates are first tinned. No. 2, the wash-pot, divided into two portions to facilitate the separation of the dross. No. 3 is the grease-pot. No. 4, the pan; and No. 5, the list-pot. The stars show where the work-people stand. In the operation of washing, the wash-man puts the plates already tinned into the wash-pot, and the heat of the tin contained in it soon melts all the loose tin on the surface of the plates: the wash-man inserts a pair of tongs into the tin, catches up a plate, brushes it on both sides with a hempen brush, dips it for a moment into the hot tin, and plunges it into the grease-pot, No. 3. The grease-pot has pins fixed within it to keep the plates asunder; and when five plates have been transferred to it, a boy removes the first into the cold-pan, No. 4; and as soon as the wash-man has transferred a sixth plate, the boy removes a second, and so on.

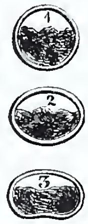
The plates are left in No. 4 until they are cold enough to be handled. As the plates are placed vertically in the melted tin and in the grease-pot, there is a *list* or selvage of tin on the lower edge of each plate, which is removed by dipping such edge into the list-pot, No. 5, which contains melted tin to the depth of about a quarter of an inch. When the list is melted, the boy takes out the plate and gives it a smart blow with a thin stick, which removes the superfluous metal. The plates are cleansed from grease by rubbing them with warm dry bran: they are lastly packed in boxes, each containing a certain number of plates, according to their quality, which is distinguished by certain marks attached to the boxes.

Stamping.—A number of small articles are produced by *stamping*. Thus, the prongs of forks are sometimes formed in this way. The fork is first forged from a rod of steel; the tang, the shoulder, and the shank are roughly made out and cut off, leaving at one end about an inch of the square part of the steel rod, which is drawn out flat to about the length of the prong. This produces a *mood* or mould (fig. 486), which being softened by heat is placed in a steel boss or die, upon which a second boss, connected with a heavy block of metal, is made to fall from the height of several feet; this forms the prongs and central part or *bosom* of the fork, leaving between the prongs only a thin film of steel, which can be cleaned out with a file. Many plated goods are formed in this way, such as the stamped fork, fig. 511. The stamp is fastened to one end of a rope, which is passed over a pulley at the top of a frame, fig. 499; while to the other end of the rope is a stirrup, in which the workman places his foot, raises the stamp to the required height, and allows it to fall suddenly upon the metal contained in the lower die. A rim of thin metal is left between the prongs and around the fork, which can easily be cleared away.

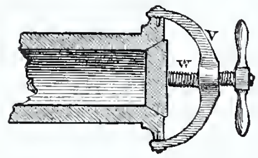
Buttons.—During many years, when it was the fashion to wear gilt buttons, the button manufacture held the foremost rank among the Birmingham "toy trades," as Hutton styles the traffic in these and similar articles. Probably no article in extensive demand is more subject to the caprices of fashion than buttons: they not only undergo frequent changes in size and form, but also in material. All the kingdoms of nature are ransacked to gratify the love of novelty: thus we have buttons of metal, of horn, of shell, of ivory, of bone, of glass, of mother-of-pearl, of jet, of precious stones, of embroidery, and of silks and stuffs of all kinds. Most of these materials must be regarded as modern innovators. The gilt button long continued to reign supreme; and was even protected by Acts of Parliament, which regulated the make, and attached penalties to any person who should presume to cover button moulds with the same kind of cloth as the coat. At the time when this absurd law was passed, silk was too costly a material for covering buttons, and other forms of covered buttons had not been invented; so that gentlemen were compelled to use the much-favoured gilt button on coats and vests. There is still a demand for the gilt button, and we cannot do better than describe its manufacture.

The gilt button is made of sheet copper, with a small alloy of zinc. Strips of this, of the proper thickness, are furnished to the button-maker; and from these *blanks* or circular pieces are cut out by means of the presses shown in fig. 513. The sharp edges of the blanks are smoothed and rounded by rolling them between two parallel pieces of steel, fig. 515; the piece *a* being movable, and the opposite piece fixed. The blanks are next smoothed on the face by means of a steel hammer, and are then ready for the shanks; these are formed by machinery, and are applied by hand (fig. 516): the shank, being placed in position, is held there by a small spring clasp; and a little solder and resin being heaped round the shank, the heat of an oven melts the solder and secures the shank. Hundreds of blanks are arranged on an iron plate and placed in the oven at the same time. If the button is to be ornamented with a crest or other device, it is

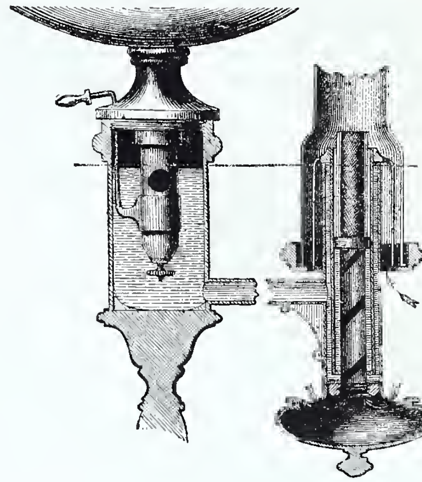
522. CANDLE.



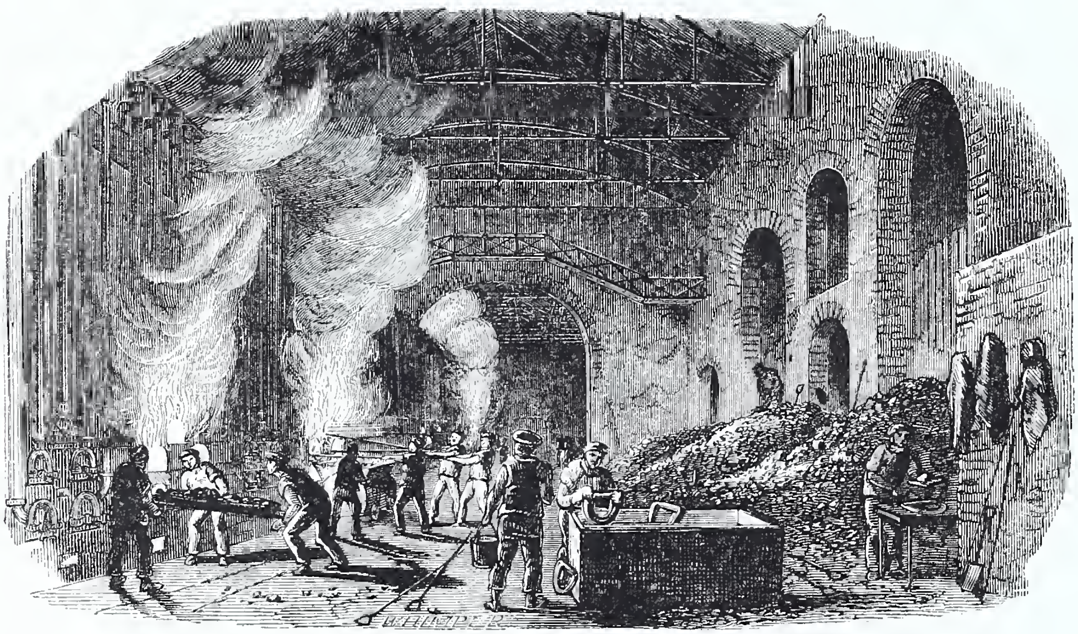
524. RETORTS.



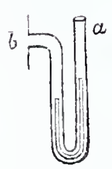
525. MOUTH OF RETORT



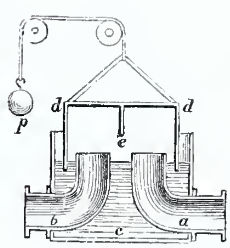
523. ARGAND LAMP.



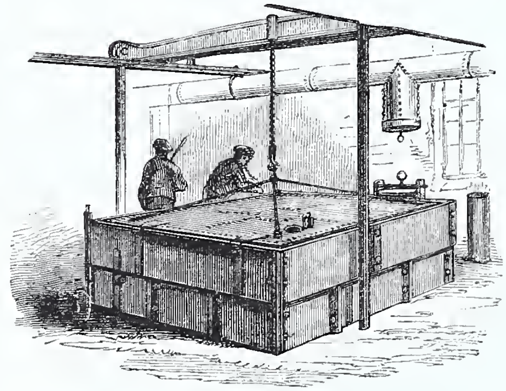
526. THE RETORT HOUSE, AT THE WESTMINSTER GAS-WORKS



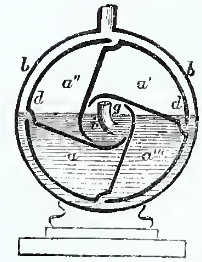
527. GAUGE.



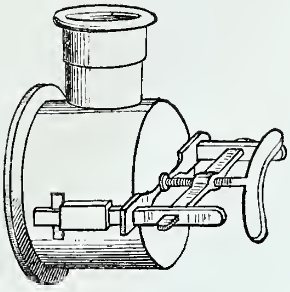
528. WATER VALVE.



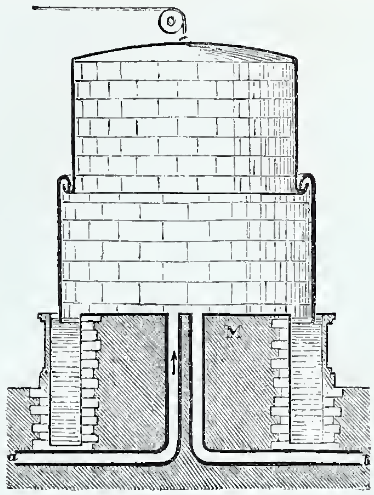
529. LIME PURIFIERS.



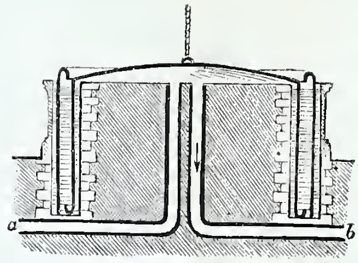
530. METER.



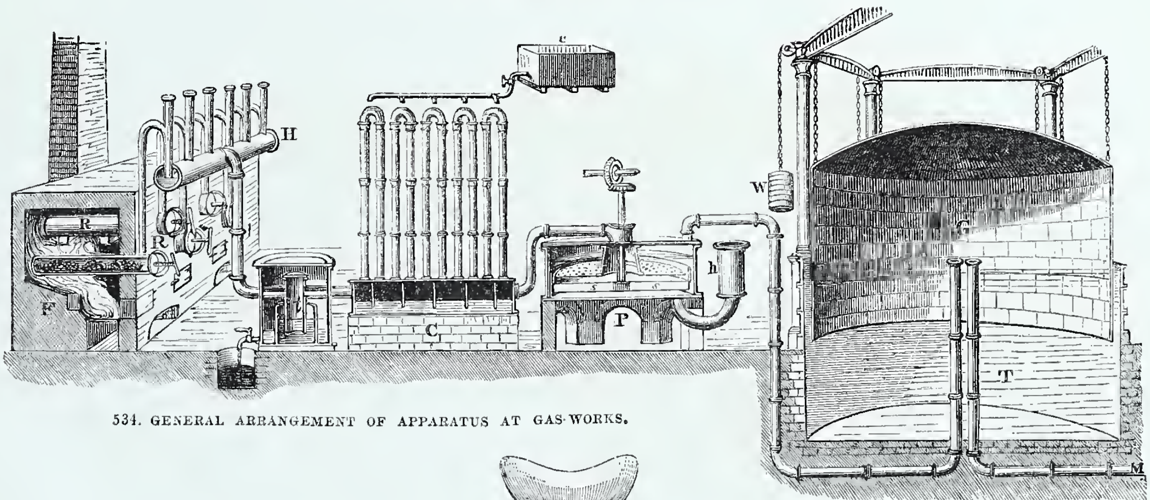
531. MOUTH OF RETORT



532. TELESCOPIC GASOMETER (*Open*).

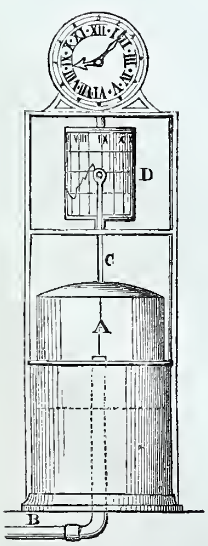


533. TELESCOPIC GASOMETER (*Closed*).

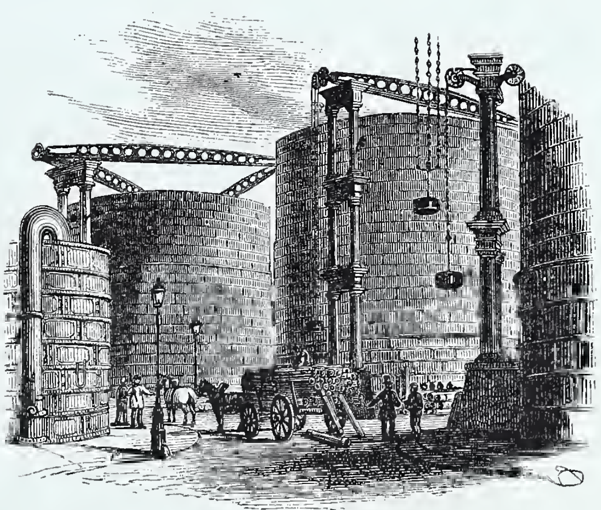


534. GENERAL ARRANGEMENT OF APPARATUS AT GAS-WORKS.

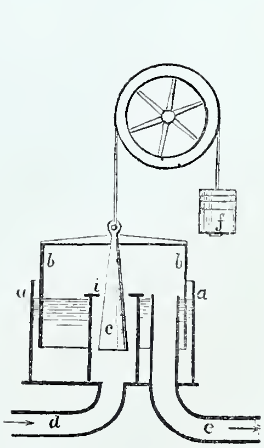
535. BAT'S-WING



536. PRESSURE INDICATOR.



537. GASOMETERS.



538. THE GOVERNOR.

passed through a stamping-press (fig. 499); the lower die containing a hole for the reception of the shank during the stamping. The buttons are next cleansed by being stirred up in a weak solution of nitric acid (fig. 514); and are then thrown into a pan containing a solution of nitrate of mercury, or *quick-water*. The gold is dissolved in mercury, from two and a half to five grains being allowed for the gilding of 144 one-inch buttons, an astonishing instance of the divisibility of the precious metal. After the amalgam has been applied, the buttons are of a dull silvery colour from the excess of mercury, which must be removed by heat before the gold makes its appearance. For this purpose the buttons are placed in a wire cage, and the cage in a furnace (fig. 517); the buttons are kept in constant motion by turning the handle of the cage; and under the influence of the heat the mercury escapes in vapour, leaving the gold equally diffused over the surface of the buttons. They come out of the furnace of a dingy gold colour, and receive their beautiful lustre by being burnished with blood-stone in a lathe (fig. 518).

A covered or Florentine button, however simple it may appear, is really more complicated in its manufacture than the gilt button just described. The various parts of the button are cut out by fly-presses (fig. 513); and those parts consist,—*firstly*, of a metal *shell* (shown in front and sideways, fig. 500); *secondly*, a metal collet, fig. 501, containing an oblong hole for the shank of the button; *thirdly*, a circular piece of silk or other woven covering for the button, fig. 502; *fourthly*, the padding which lies under the collet, round which is wound, at right angles to the length of the oblong hole of the collet, a thread (as shown in fig. 503), which acts as a flexible shank to the button. The padding consists of several layers of paper, and a piece of silk or other fabric similar to the covering for forming the back surface. The various disks, consisting of the silk covering, a disk of paper to prevent the metal shell from cutting the silk, and the shell, are shown in fig. 504, as they are placed upon the die or mould, fig. 505. They are pressed down to the bottom of the die by means of a punch; and when this is removed, a hollow tool, fig. 506, is forced into the die, by which means the edges of the silk are brought towards the centre and made to overlap the edges of the shell. The collet, with the padding, is then dropped into the mould through a hollow tool, fig. 507; when a punch is brought down so as to force the padding and the edges of the outer covering into the shell. The button is then removed from the mould, fig. 505, by passing a wire up through a channel made for the purpose; and the final pressure is given to the button by means of a punch, fig. 508, for which purpose the button is put into the mould with the collet downwards and pressed into the die by the flat face of the punch.

Pins.—The manufacture of a pin is as remarkable in its way as that of a needle, and furnishes another instance of the value of subdivision of labour. Where a number of operations are required in the production of one article, it is desirable to keep one person or set of persons to one operation, so that by constant practice he may attain skill and rapidity in his particular department.

The pin-maker receives wire from the wire-drawer in a soft state, usually larger than he requires it. It is first cleansed by means of dilute sulphuric acid, and reduced to the required gauge or size by passing it through a draw-plate. It is straightened by pulling it through another draw-plate from the barrel on which it is wound, and running it out upon a low wooden bench to the length of twenty feet (fig. 519). That piece is then cut off, and another portion is similarly drawn out. These lengths are then cut up by shears into shorter lengths, each of which is capable of furnishing rather more than six pins. These lengths are next pointed at both ends at a machine called a *mill*, consisting of a circular single-cut file and a fine grit stone (fig. 521). As many as from fifty to eighty of the pin wires are held at the same time, a rotatory motion being given to them by the motion of the thumb and fingers. The fine brass dust thus produced is very injurious to health, unless the mill is properly ventilated. From the ends of each wire thus pointed, lengths are cut off, sufficient for two pins, and the intermediate portions returned to the pointer, who points the extremities as before; two lengths are again cut off from each wire, and the intermediate portions being again pointed furnish each two pins. The wire for the pin-heads is coiled in a compact spiral round a wire of the size of the pins; the central wire is then withdrawn, and two or three turns of the spiral are cut off for each head. The heads are put on by a girl, who is seated with a number of heads in her apron; and taking up a number of headless pins between her fingers, moves them through the heads with a threading kind of motion. The wires catch up a head, or it may be two or three heads each; the superfluous heads are stripped off, and the pins are placed one at a time in a mould, beneath a hammer which can be raised by the foot (fig. 520). The pin being in its place, point downwards, the hammer is allowed to descend; and, striking the top of the pin, moulds and fastens the head, and leaves the top smooth and round. The man instantly raises the hammer again; when a little spring under the die raises the pin so that it can be instantly removed, and another made to take its place. In this way a man will head 1,500 pins per hour. In this state the pins are dingy and dirty; they are cleansed by being boiled in sour beer or a solution of tartar. Then comes the *whitening* or tinning: for which purpose about six pounds of pins are put into a copper pan, then seven or eight pounds of grain tin, then more pins, and more tin, until the pan is filled. Water is next poured in, and the pan is set on the fire; and when it is hot, the surface is sprinkled with cream of tartar, and the boiling is continued for an hour. The pins are taken out, washed, and the operation is repeated, if necessary. After the tinning, the pins are polished by being shaken in a leathern bag with bran. The bran is separated by winnowing, and the pins are collected in bowls for papering. The papers are crimped by means of crimping-irons; and the folds for one row being gathered together are placed between the jaws of an iron vice, which close by means of a spring. There are grooves across the jaws of the vice, to guide the paperer, who sits with her lap full of pins. Instead of taking them up one or two at a time, she passes a pocket-comb through the pins and takes up the number required for one row; and directing the points along the grooves, pushes the pins into the paper with great rapidity, by means of a metal guard on the left hand. She then pulls open the vice, gathers together the next row of folds, places them in the vice, and fills them as before.

Most of the processes above described can be imitated by machinery, in which case the head is formed by hammering out, or *upsetting*, the end of the wire between dies; but the chief objection to solid-headed pins is, that a soft wire is necessary, so that machine-made pins are more liable to bend than those made by hand.

XXVIII.—ARTIFICIAL ILLUMINATION—GAS.

The useful arts have been popularly arranged under the three great heads of FOOD, SHELTER, and CLOTHING. Without pausing to inquire into the accuracy of such a classification, we must admit that it includes a vast number of processes on which our physical comforts depend. Each of these terms, however wide its meaning, has different meanings among different people, and in different states of civilisation. As man advances in wealth and intelligence, his food becomes more delicate, his dwelling more luxurious, and his clothing more refined ; and the delicacy, the luxuriousness, and the refinement will vary with the climate, and with the natural productions of that part of the world which he inhabits. They will even vary according as he occupies an island or a continent, dwells near the sea or a great river, and is dependent for the supply of foreign produce on land or water carriage. Still, whatever be his condition and wherever he may dwell, he can scarcely fail to be benefited by the discoveries of science, and the improvements in the useful arts consequent thereon. The African chief, who employs his people in collecting and shipping off to this country the palm oil which we now so extensively employ, receives our manufactures in return ; and it was not very long ago that an iron house of two or three stories, with its furniture complete, was sent out as a residence for one of these dusky chiefs. Discoveries in chemistry, and the abundant supply of this palm oil, have enabled us greatly to improve our means of artificial illumination, just as the introduction of gas, early in the present century, improved our shops and streets, by making those more attractive and these more secure. Such improvements as these are among the landmarks of civilisation. Inhabiting, as we do, a rigorous and uncertain climate, we create within our dwellings an artificial climate, suited to our wants, and artificial light, adapted to our occupations ; thus bringing, as it were, the amenities of the south into the winter of the north. Nor do the advantages of these comforts end with the comforts themselves ; the energy and enterprise required to secure them react favourably upon ourselves, and tend, among many other causes, to produce a race far superior to the inhabitants of the land where each man is said to have done his duty to society if, once in the course of his life, he plant a single bread-fruit tree ; since nature will accomplish the rest, in supplying him and his family with food, shelter, and clothing.

There are few contrivances in the useful arts more beautiful than a candle. This is an ingenious contrivance for constantly supplying a flame with as much melted fat or other proper material as can be consumed without smoking. To this end the size of the wick must be nicely adjusted to the thickness of the tallow: if the wick be too large, there will be too much heat, too much melting of the tallow, and the candle will gutter ; if the wick be too small, there will not be enough heat, and the tallow will form into a ring-shaped wall about the flame, as is the case in night lights. But when the wick is of the proper size, the tallow immediately below the flame is melted into the form of a hollow cup (fig. 522), which forms a reservoir, always properly filled, for feeding the flame. The fibres of the twisted cotton of the wick act as a number of capillary tubes, and carry the liquid fat up into the flame ; where, being exposed to a high temperature, and sheltered from the air, it undergoes a dry distillation: it is decomposed into an inflammable vapour, which rises by its lightness, and undergoing combustion as it rises, rapidly diminishes in quantity until it disappears in a point.

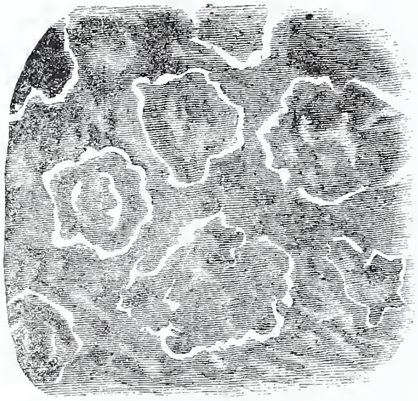
The flames used for artificial illumination, whether obtained from candles, lamps, or street gas, are produced by the combustion of compounds of hydrogen and carbon. These hydro-carbons, as they are called, consist of hydrogen gas holding carbon or charcoal in solution. The hydrogen supplies the flame, and the carbon the brilliancy: the flame of pure hydrogen has little or no illuminating power ; but if we project through it a quantity of iron filings, or of charcoal powder, the flame immediately becomes brilliant. That all common flames contain charcoal in a state of minute division is evident from the fact that, if we introduce a cold body into a flame, the charcoal condenses upon it ; or if we hold the flame of a candle near the ceiling of a room, it leaves a black mark from the precipitation of the carbon on the cold surface.

As soon, then, as the tallow is drawn up into the flame, it is resolved into a gaseous hydro-carbon ; but combustion only takes place at the exterior of the flame, where it is in contact with the oxygen of the atmosphere. Here the oxygen unites with the hydrogen of the flame, and forms vapour of water ; and here too, the particles of carbon, coming to the surface, are seized on by the oxygen, undergo combustion at a white heat, and pass off in the form of invisible carbonic acid gas. No combustion is going on within the flame, but only distillation and decomposition, so that flame has been appropriately termed a luminous bubble of gaseous matter.

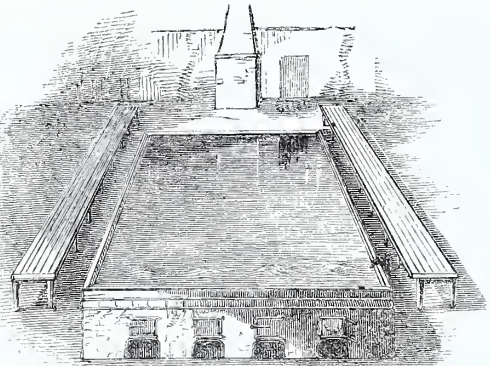
The fibres of the cotton within the flame are charred by the heat, but not burnt, on account of the absence of air ; so that it is necessary to get rid of the accumulating wick by means of snuffers. In composite candles, however, the wick is plaited, so that the end bends considerably, and is thus brought out of the flame and consumed, a plan which could not be adopted with tallow on account of the guttering.

In the combustion of oil in a lamp, similar changes to those which take place in the flame of a candle go on. The oil is drawn up into the flame by capillary attraction, and is converted into a gaseous hydro-carbon. It is of no consequence to the theory whether the wick be a solid bundle of fibres or a thin circular band. The antique lamp of the ancients, however we may admire it for its grace and beauty of form, must have been a smoky, badly-smelling utensil ; but the solid wick continued in use until the year 1789, when a Frenchman, named Ami Argand, invented the lamp which still perpetuates his name. This was a grand improvement in artificial illumination : its most important features were the disposing of the wick in the form of a ring, and inclosing the flame within a glass chimney. By this means a double current of air was supplied, as shown in fig. 523 ; one current setting in from the bottom of the glass and feeding the air on the outside of the ring of flame, and the other current setting in through the apertures at the bottom of the well, and passing up through the interior of the ring. It must not, however, be supposed that by this arrangement flame ceases to be a luminous bubble of gaseous matter : the form only is changed, since in the Argand lamp we have a couple of concentric luminous rings, the space between them being filled with inflammable vapour, where no combustion is going on.

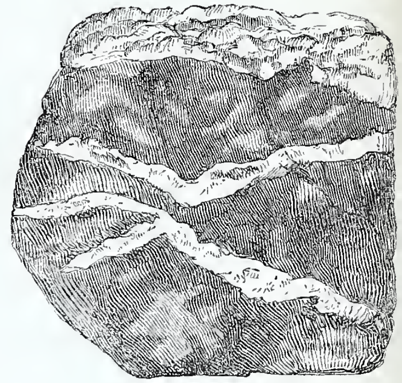
In a gas flame the gaseous hydro-carbon is prepared beforehand, stored up in vessels the pressure of which keeps up a constant supply to the burner. Gas has been prepared by the distillation of tallow or of oil ; but in a country abounding in bituminous coal (which is used, we think, with so much unwise extravagance), that material would be the cheaper source. A ton of Newcastle coal yields about 9,250 cubic feet of gas, and about thirteen cwt. of coke. The coal is distilled in *retorts*, or hollow flattened cylinders of iron or of clay, fig. 524, No. 2 or No. 3 being preferred. The retorts are set in stacks of three or five, arranged in long brick furnaces (fig. 526) ; the mouths of the retorts project from the furnace, and are fitted with movable lids, which can be closed air-tight by a clay luting, and fixed by means of a screw, W, fig. 525, and a holdfast, V. Another mode of securing the mouth is shown in fig. 531. The retorts R are shown more clearly in their position in the furnace F, at the left hand of the general arrangement shown in fig. 534. From the upper part of the mouth of each retort, fig. 531, is a socket for the reception of a tube which passes up some way, and then bends into a long,



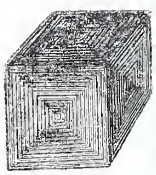
539 ROOFING SALT.



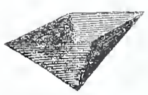
540. EVAPORATING PAN.



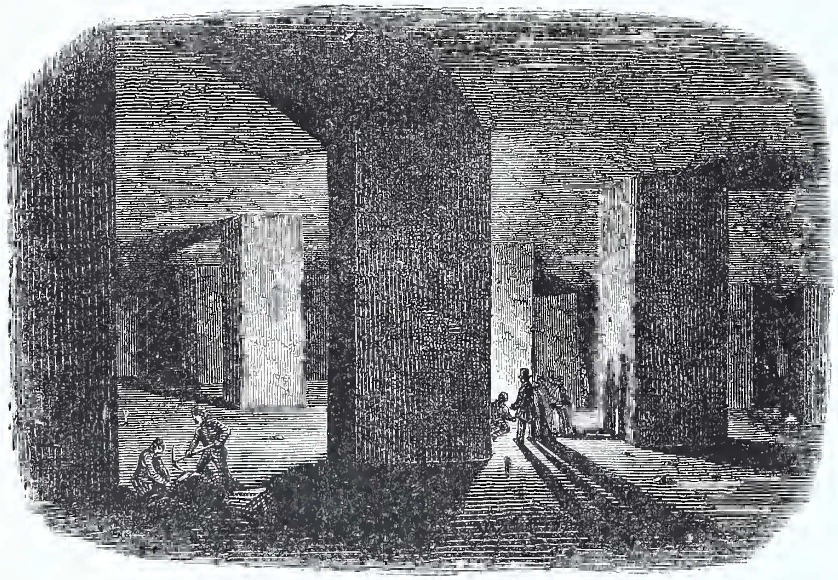
541. ROCK SALT.



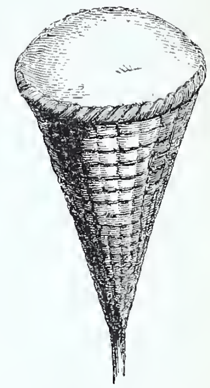
542. CRYSTAL OF SALT.



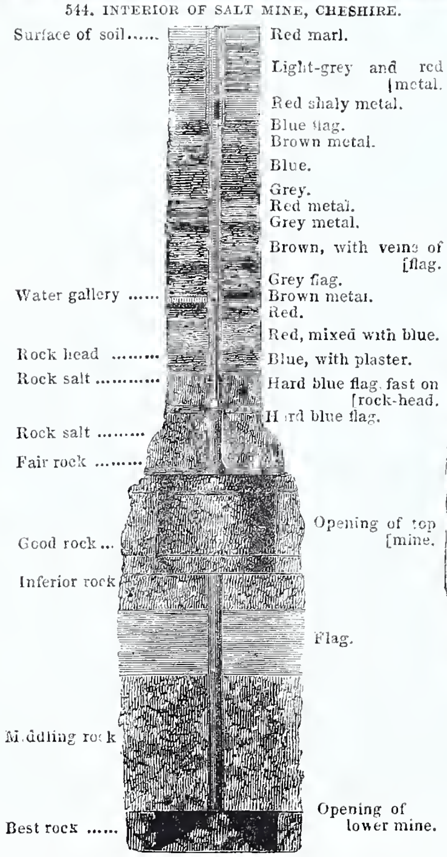
543. PORTION OF CRYSTAL.



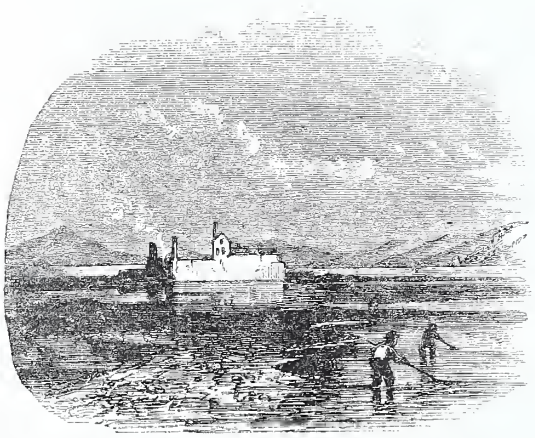
544. INTERIOR OF SALT MINE, CHESHIRE.



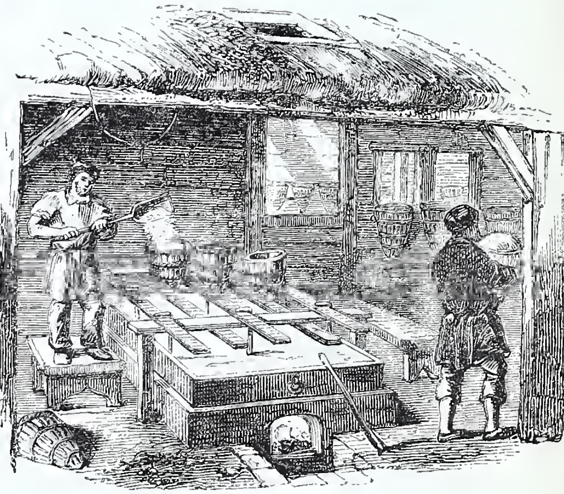
545. DRAINING SALT.



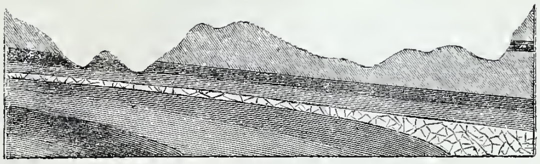
547. SECTION OF THE WHARTON SALT MINE, ON THE RIVER WEAVER, CHESHIRE.



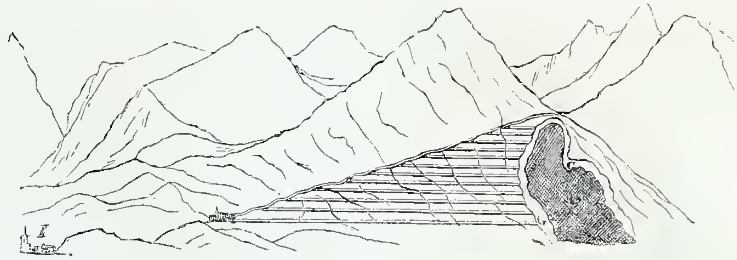
546. SALT PAN ON THE FORTH.



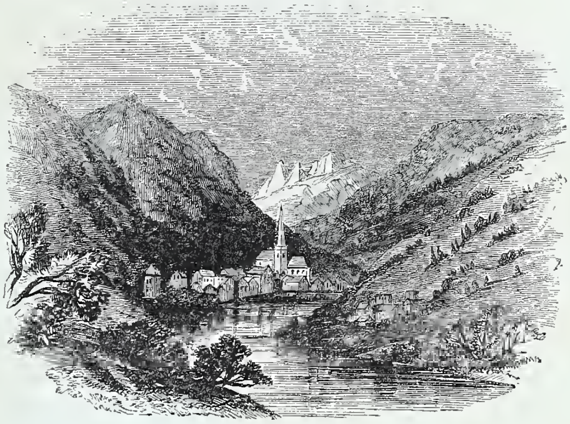
548. SALT PAN.



549. DEPOSIT OF ROCK SALT IN WIRTEMBERG.

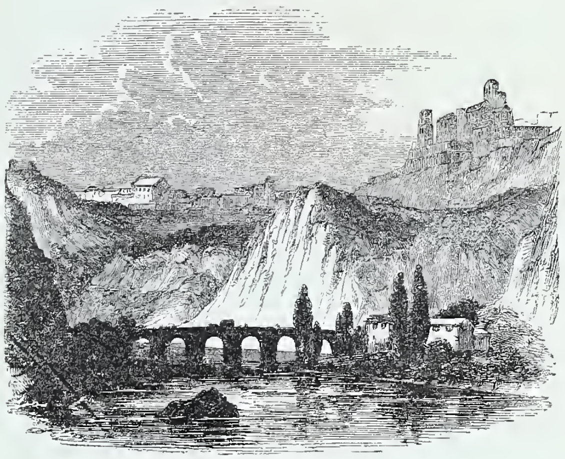


550. METHOD OF WORKING SALT AT ISCHL.

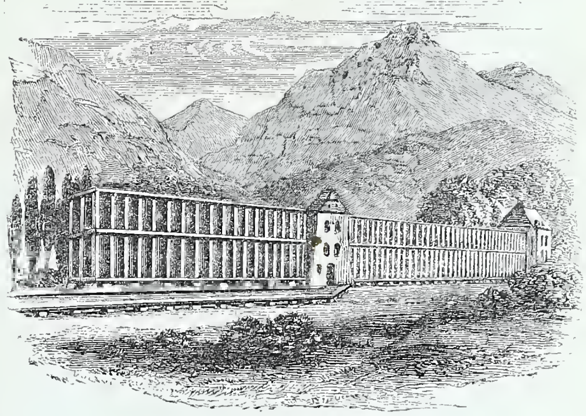


551. ISCHL.

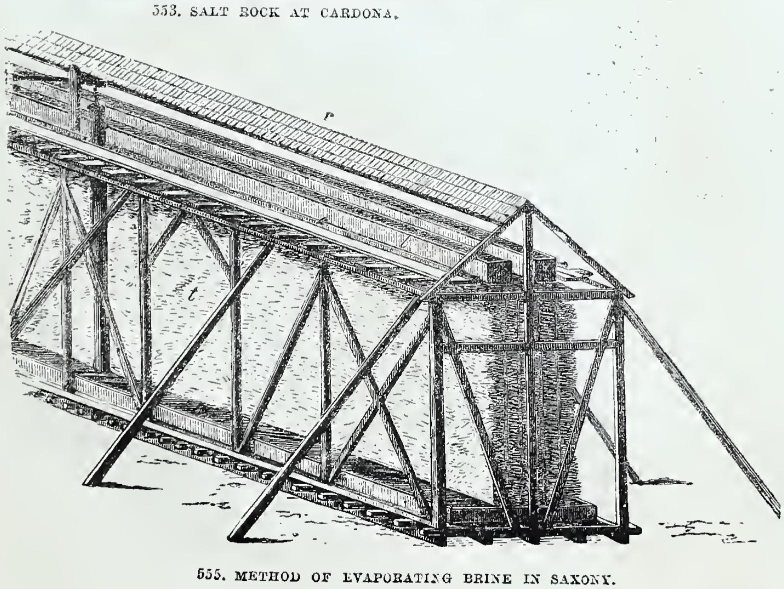
552. HALL.



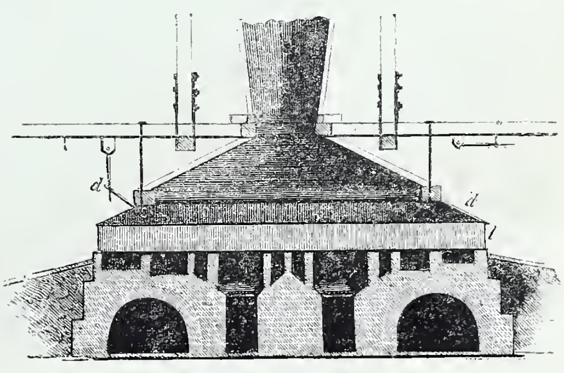
553. SALT ROCK AT CARDONA.



554. THORN-HOUSE AT MOUTIERS.



555. METHOD OF EVAPORATING BRINE IN SAXONY.



556. EVAPORATING PANS.

wide pipe, called the hydraulic main, H, fig. 534, which passes horizontally along the front of the whole range of furnaces. This main pipe is kept half filled with tar and moisture derived from the coal, and in it the pipes from the retort terminate; so that they are closed by means of a water valve, which permits one retort to be cleared out and recharged, without interfering with the other retorts which are in action. As the tar accumulates in the hydraulic main, it overflows into the tar-well *t*, whence it is drawn off into a well sunk in the ground. In from four to six hours from the time of charging the retorts, the coal will have given off all its gas: the mouth of the retort is opened, the coke is raked into iron boxes, moving on wheels (fig. 526), and is extinguished by pouring water over it, while a fresh supply of coal is introduced by means of a long scoop, as shown in the same engraving. The mouth of the retort is instantly closed, and the distillation proceeds as before. In the mean time, the gas from the various retorts having deposited in the hydraulic main most of the tar, and some of the water and ammonia, with which it is charged, passes through a system of pipes, C, called a *condenser*, which is kept cool by water flowing over it, from a cistern, *c*. The effect of this refrigeration is to remove from the gas most of its remaining tar and aqueous vapour. The gas, however, is still too impure for use: it contains carbonic acid, sulphuretted hydrogen, cyanogen, naphthaline, ammonia, and some other matters, which are removed by causing the gas to pass through the lime purifiers P, one of which is shown separately in fig. 529; only this is what is called a dry lime purifier, and that in fig. 534 is a wet one, the lime being made up into a cream with water, when it is poured into the reservoir *h*, and is agitated with the stirrer *s*. It is now common to pass the gas through what is called a *scrubber*, which consists of a tower filled with small coke, with water streaming down it; while the gas entering from below meets with the shower, which deprives it of the last traces of ammonia. The gas, after purification, passes along a pipe into a large reservoir or gasometer of metal, G, consisting of a bell of sheet iron, inverted in a tank, T, containing water, in which the gasometer rises and falls. The bell is nearly counterpoised by weights and chains passing over pulleys, W, presenting the effect shown in fig. 537. When the gasometer is full, its descent forces the gas along the main M, by which it passes to the pipes of the consumers. Gasometers are sometimes made of the form represented in fig. 532, in two or three parts: the rim of the upper part is curved upwards and filled with water, so as to form a channel and water joints for the reception of the recurved rim of the upper part of the lower portion; and the tank in which they dip is merely a ring of water surrounding a central core of masonry, M. The gasometer in its collapsed form is shown in fig. 533: the gas enters by the pipe *a*. The supply of gas to the mains requires careful regulation, since it must be varied at different hours, it being greatest when the shops are open, and diminishing as the night advances. The pressure is known by means of an *indicator*, fig. 536, which consists of a small gasometer, A, rising or falling in a tank, according as the pressure varies in the main, with which it is connected by a small pipe, B. To the upper part of the gasometer is fastened a vertical rod, C, carrying a black-lead pencil, which presses against a cylinder, D, covered with a sheet of paper, ruled so as to mark the twenty-four hours of the day. By connecting the cylinder with a time-piece, it is made to rotate on its axis, by which means the pencil draws a line opposite the hour when it is set going. If the pressure be constant for a number of hours, the line will be straight; but if the pressure vary, it will be zigzag; the amount of pressure being indicated by the horizontal lines into which the paper is divided: a new paper being added every twenty-four hours, a constant record is thus preserved of the pressure kept up on the gasometers which supply the mains. The amount of pressure is ascertained by means of a small gauge, fig. 527, consisting of a bent tube screwed into the gasometer at *b*, and open to the air at *a*. Mercury is poured in, so as to occupy the bend of the tube and to rise up a little way in each limb. If the pressure be the same within the gasometer as that of the air outside, the mercury will stand at the same height in both limbs: if the pressure be greater in the gasometer than outside, the mercury will be depressed in *b* and rise in *a*, which is the case in the present example.

In small gas-works the pressure is regulated by a self-acting instrument called the *governor*, fig. 538. *a* is a tank, in which the regulating vessel *b* floats in water; *c* is a metal cone attached to the top of *b*; the gas enters by the pipe *d*, on the top of which is a perforated plate, *i*; *e* is the outlet pipe by which the gas escapes into the street mains; *f* is a counterbalance; when this is small, the pressure is of course greater than when it nearly counterpoises the vessel *b*. When the consumption of gas from the mains is steadily maintained, the supply by the pipe *d* adjusts the vessel *b* to a certain height, and the cone *c* takes its place in the opening *i*, so as to admit into *b* a quantity of gas equal to the demand. Should the demand on the mains increase, the vessel *b*, and consequently the cone *c*, will descend a little, thus enlarging the opening at *i* and admitting more gas from *d*. If, on the contrary, the demand on the main should diminish, *b* will rise, and the cone *c* will contract the opening at *i*, thus diminishing the supply from *d*. This arrangement of the cone *c* in the opening *i* is called a *throttle-valve*.

The gas meter, by which the consumer registers the amount of gas burnt, consists of an outer case, *b*, fig. 530, more than half filled with water, and an inner drum (*d*), moving round on two pivots, placed horizontally, and divided into four compartments, $a\ a'\ a''\ a'''$, by partitions, which are bent so as to form a central space (*g*). The gas is supplied by a tube (*i*), and as one of the four spaces becomes filled with gas it becomes lighter, and causes the drum to turn round a quarter of a revolution; when, rising above the level of the water, the gas passes into the outer case, and up a tube at the top which supplies the burner. While one partition is rising and discharging its gas, another is being brought under the water and being filled; thus, so long as gas is being burnt, the drum *d* is revolving; and by an arrangement of wheels, hands are made to move upon dial plates, which register the number of cubic feet of gas consumed.

Fig. 528 represents a *water-valve*, which is useful for making connexions between pipes, such as those which connect the first lime purifier, fig. 529, with the second, the second with the third, &c. The floating vessel *d* has a partition (*e*), which descends so as to come into contact with the water in the cistern *c*, when it is desired to shut off the supply of gas. This partition is placed between the two pipes *a b*, one of which is the inlet and the other the outlet pipe. By increasing or diminishing the counterpoise *p*, the partition recedes from or approaches to the surface of the water in the cistern, and assists or retards the flow of gas from the inlet to the outlet pipe.

The arrangements for supplying gas in a large city are on an enormous scale. London and its neighbourhood are supplied by fifteen gas companies. The Westminster gas works alone are accustomed to supply as much as 5,000,000 cubic feet of gas in one night from their three stations. Gasholders have also been enormously increased in size; one such vessel being sometimes of the capacity of 1,000,000 cubic feet, or 140 feet in diameter and 70 feet in height. The counterpoise weights and chains are now dispensed with, the weight of the gasometer being sufficient for its stability.

The best form of burner is that on the Argand principle, in which the holes for the escape of the gas are arranged in a circle. Single jets without a glass chimney are of various forms, such as the *swallow-tail*, where the gas issues from two holes so inclined that the streams cross each other and produce a broad continuous flame. When the gas escapes by a narrow slit by the top of the burner, it produces what is called the *bat's-wing*, fig. 535; there are also the *fish-tail*, and some others.

XXIX.—SALT.

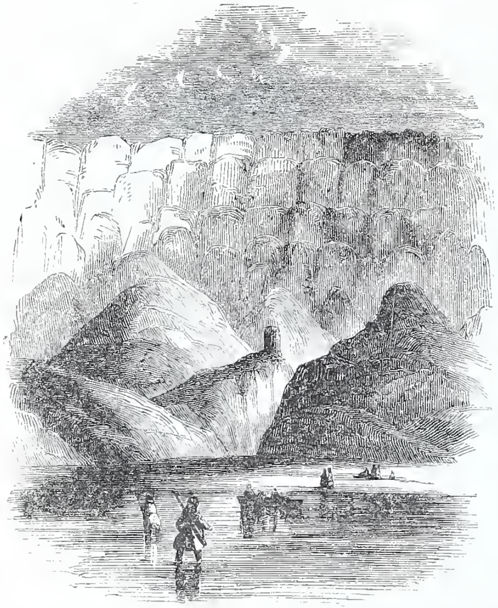
Common salt (*chloride of sodium*), which enters into the composition of bread and other kinds of food, and is eaten with meat and vegetables, is one of the necessaries of life, and is therefore supplied to us by Nature's bountiful hand in inexhaustible quantities. Every gallon of sea-water contains nearly four ounces of salt; it is stored up in the solid form in vast deposits at a moderate depth in several parts of the continent of Europe; or it is found in brine-springs, from which it may be obtained by evaporation. Some parts of the world, however, are not so favoured; as in Central Africa, where salt is described as the greatest of all luxuries, and a child sucks a piece of rock salt with as much relish as our little ones consume barley-sugar. The vast continent of America is also scantily supplied with salt: thus, trade and commerce arise from the abundance of supply on the part of one nation and its deficiency on that of another; and often by means of this intercourse a secondary advantage arises, which is of far greater importance than the primary one, namely, the preaching of the Gospel in the farthest ends of the earth.

The deposit of salt among rocks of almost all ages is an interesting and important fact, not easy to account for. Some suppose the rock salt (or *sal gem*, as it is called from its beautiful gem-like appearance) to have been deposited by saline lakes, or even by the sea, which once covered and afterwards quitted the place; but the purity and solidity of the masses, their bulk, and peculiar and insulated positions, render these suppositions unlikely. Fig. 549 represents a deposit of rock salt at Whimpfen, in Wirtemberg: fig. 550 represents the deposit at Ischl, in Upper Austria, among beds of limestone rock. The deposit is worked by means of twelve horizontal galleries cut in the face of the mountain. The salt mass S is separated from the limestone by bands of gypseous marls, G. The position of the town of Ischl is shown at I, and also in fig. 551. The salt mines of the Tyrol are situated near Hall, in the valley of the Inn, fig. 552. Fig. 553 represents the salt rock at Cardona. In our own country, Cheshire is distinguished for its salt; the principal deposit occurs near Northwich, in two beds situated one above another, separated by about thirty feet of clay and marl, intersected with small veins of salt; the two beds together are not less than sixty feet in thickness, three hundred feet in breadth, and a mile and a half in length: these beds occur in magnesian limestone. Fig. 547 shows a section of a salt mine, on the river Weaver. The strata passed through usually consist of clay and gypsum in various proportions. The workmen call the clay red, brown, and blue *metal*, according to its colour; and the gypsum they name *plaster*. Fig. 544 represents the interior of a salt mine, with pillars supporting the roof. The appearance of the roof, with portions of earth mixed with the salt, gives the effect of a rude mosaic, fig. 539; while fig. 541 represents veins of rock salt in crevices of the rock, tinged red with oxide of iron. The rock salt is contained in masses of considerable size, differing in form and purity; they are separated by the usual operation of blasting, and with the aid of miners' tools. The rock salt is raised to the surface by steam-power; but horses are employed underground for conveying the rock to the bottom of the shaft.

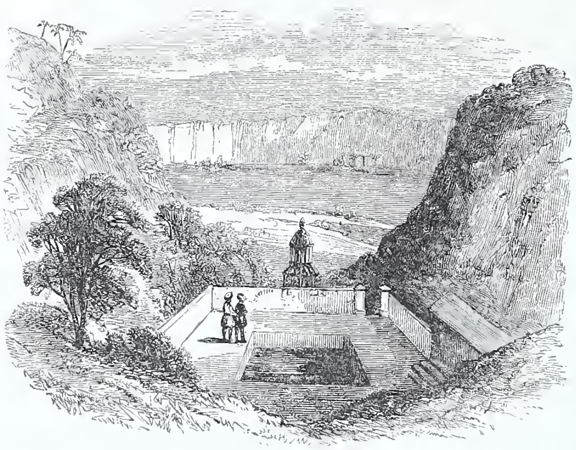
When water comes in contact with these deposits, brine-springs are formed; these are not uncommon in the valleys of the Weaver and the Wheelock. In using the brine for the manufacture of salt, a shaft is sunk down to it, and it is pumped up as it is wanted into evaporating pans, fig. 540; these are of wrought iron, oblong in shape, and from twelve to sixteen inches in depth; there are three or four fires to each pan. At one end of the pan-house is the coal-hole, and at the other end a chimney; along each of the two remaining sides is a walk, five or six feet wide, occupied by benches, on which the salt is placed in conical baskets to drain, after it has been taken out of the pan. The mode of manufacture is varied, according as it is intended to produce *stoved* or *lump salt*, *common salt*, *large-grained flaky*, and *large-grained* or *fishery salt*. The effect of these variations will be understood by examining a crystal of salt. The natural form of the crystals of pure chloride of sodium is that of a perfect cube, fig. 542; and they constantly assume this figure when the proper arrangement of their particles has not been interrupted by agitation, or the application of too strong a heat. Every perfect cube is composed of six quadrangular hollow pyramids, fig. 543, joined by their points and external surfaces; each of these pyramids, filled up by others, similar but gradually decreasing, completes the form. Each of these pyramids is composed of four triangles, and each triangle is formed of threads parallel to the base, which threads consist of a series of small cubes. These cubes dissolve in about three parts of cold water, and they are scarcely more soluble at a temperature of 212°.

In making the stove or lump salt, the brine is brought to a boiling heat, or 225°. Crystals of salt are soon formed on the surface, and fall to the bottom as they form. In about twelve hours most of the water has evaporated; the fires are slackened, and the salt is drawn to the sides of the pan with iron rakes. It is then placed in conical baskets, fig. 545, to drain (see also fig. 548), and the drying is completed in stoves. The pan is filled twice in the course of twenty-four hours; and impurities which rise to the surface are skimmed off before the brine boils. In making common salt, the pan is filled but once in the course of twenty-four hours. The brine is first brought to a boiling heat, when the fires are slackened, and the crystallization is carried on at about 160° or 170°. The salt forms in pyramids of close compact texture, clustered together, with cubical crystals intermixed. The large-grained flaky salt is crystallized at 130° or 140°, and the pan is filled once in forty-eight hours. This salt is somewhat harder than common salt, and approaches nearer to the natural form of the crystals. In making the large-grained or fishery salt, the brine is heated to 100° or 110°, so that the crystallization proceeds more slowly than in making the other kinds: salt forms in large cubical crystals, and five or six days are required to evaporate the brine. The reason why the large-grained salt is better fitted than small-grained salts for the packing of fish and other provisions is, that the large crystals, from their hardness and compactness, retain their solid form longer, and are very gradually dissolved by the fluids which exude from the provisions; thus furnishing a slow but constant supply of brine. But in preparing the pickle, or *striking* the meat, by immersion in a saturated solution of salt, the smaller-grained varieties are to be preferred, on account of their greater solubility.

Natural salt springs are usually only slightly impregnated with salt; but there are many inland situations where the cost of carriage renders the importation of salt very costly, so that it is advantageous to obtain a supply from the weak brine of these springs. But as the cost of fuel might become a more serious charge than that of carriage, successful attempts have been made to evaporate the brine in the open air, so as to concentrate it before it enters the evaporating pan. Thus, at Moutiers, in Sardinia, the strongest spring contains less than two per cent. of saline matter, and in most of them only one pound and a half of salt can be obtained from thirteen gallons of water. In order to concentrate it by natural evaporation, the weak brine is spread over as large a surface as possible, since the rate of evaporation depends on the temperature and the amount of surface exposed. The evaporating houses, fig. 554, are each 350 yards in length, twenty-five feet in height, and seven feet wide. They consist of a frame of wood filled with double rows of fagots of black-thorn

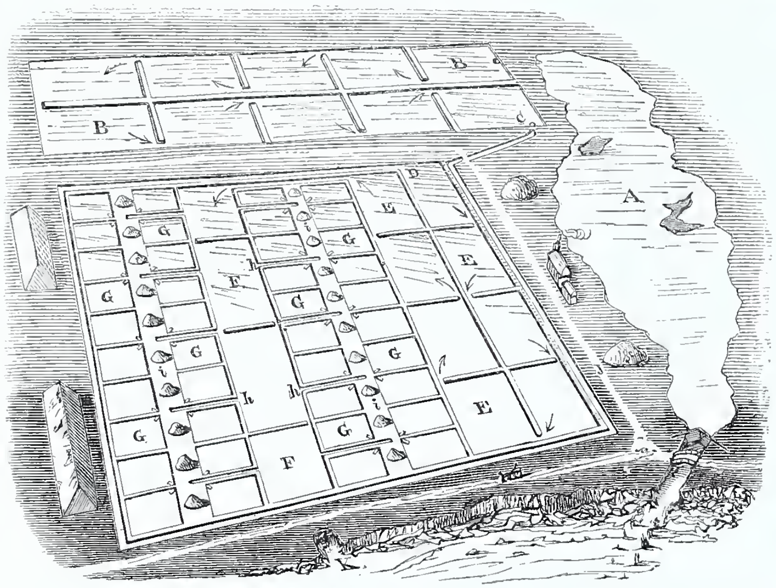


557. PILLAR OF SALT.

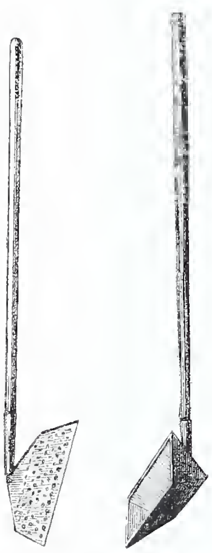


558. SALT LAKE IN INDIA.

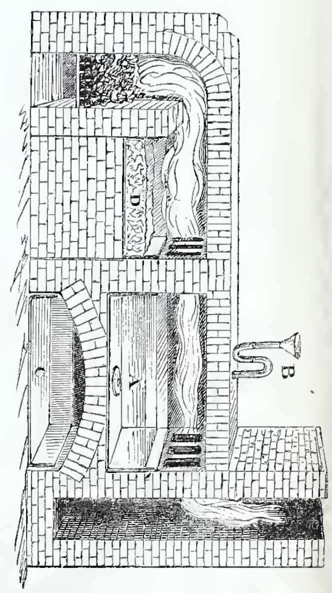
559. WADY MOJEB.



561. SALTERN.

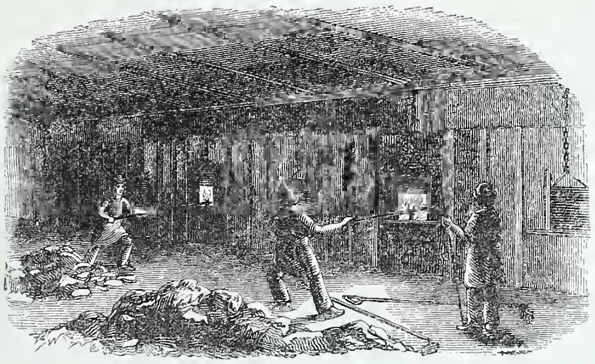


560. SALT TOOLS.



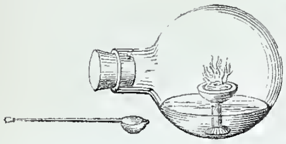
563. SODA FURNACE

562. SHORE OF THE DEAD SEA

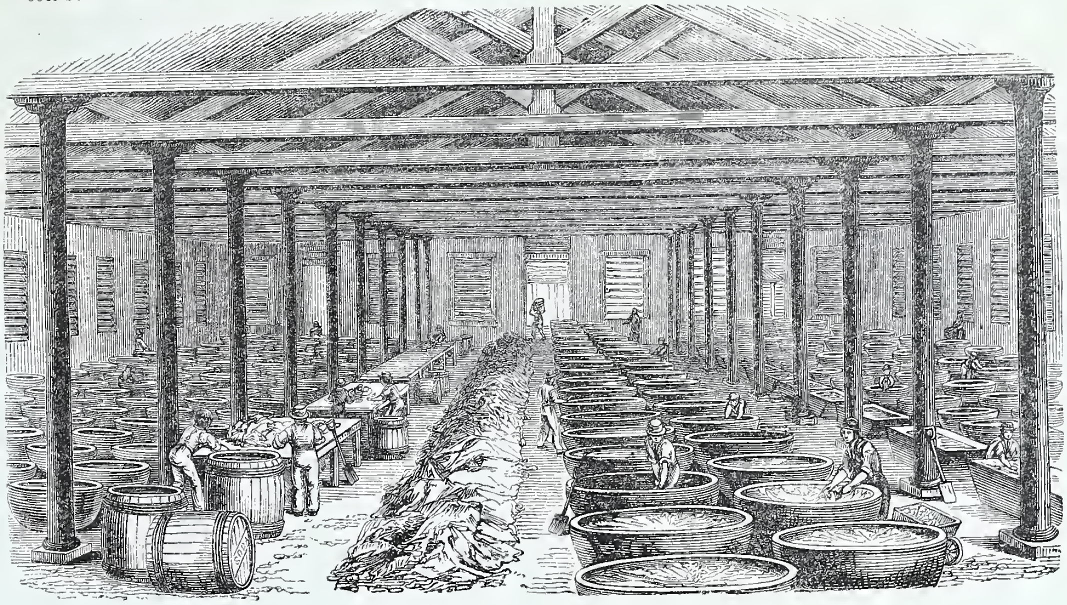


564. SODA FURNACES.

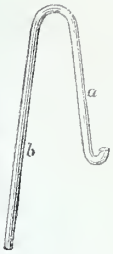
565. BLACK-ASH VATS.



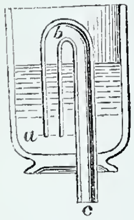
567. SULPHURIC ACID GLASS.



566 SODA CRYSTALLIZING HOUSE.

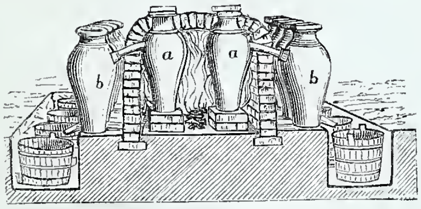


569. SYPHON.

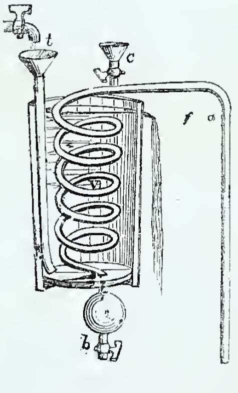


568 SYPHON-CUP.

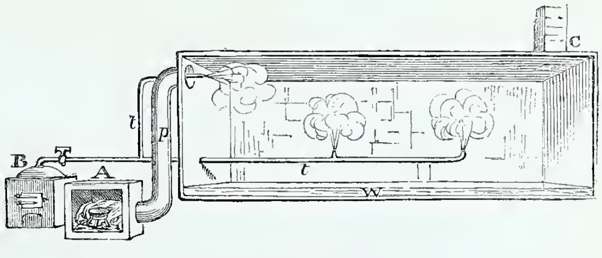
570. OPENING.



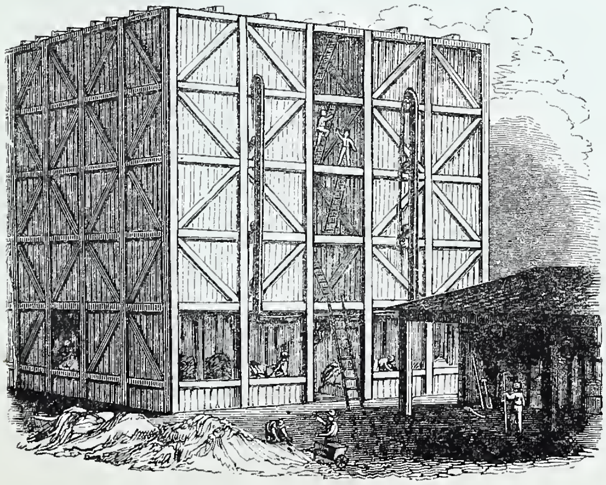
571. DISTILLING SULPHUR.



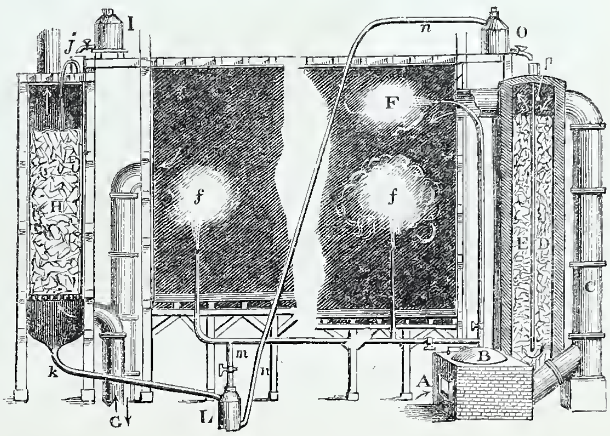
572. WORM-SYPHON.



573. SULPHURIC ACID CHAMBER.



574. SULPHURIC ACID CHAMBERS.



575. SULPHURIC ACID CHAMBER.

(whence these houses are called *thorn houses*); and in the midst is a stone building containing a hydraulic machine for pumping the water to the top of the building, whence it passes into canals on each side, which extend the whole length of the building; from these canals it passes into smaller channels, from which it trickles through a multitude of small holes in a very gentle shower upon the fagots, where it is divided into an infinite number of drops, falling from one point to another. The evaporating surface is thus indefinitely enlarged; and as the thorn house is placed so as to catch the currents of wind that rush down the valley, the amount of evaporation is very large. By repetitions of the process the water is at length nearly saturated, and is then passed to evaporating pans, where the salt is crystallized in the usual manner.

The arrangement at the Saxon salt works is similar to the above, and will be understood by reference to fig. 555; in which *t* is the wall of black-thorn fagots, covered by a roof, *r*, the greater portion of which, however, is removed in the engraving in order to show the details; *b* is one of the canals supplied with brine from the upper reservoir, and *c* is the perforated channel from which the brine falls drop by drop upon the fagots. The process can be repeated by pumping the brine up from the lower tank. The brine which is concentrated or *graduated*, as it is called, during the fine season, is stored up in vast reservoirs of masonry, where it deposits impurities. The boiling is carried on during the winter months only; the evaporating pans, fig. 556, are furnished with a roof-shaped hood of boards, with a trunk at *s* for carrying off the steam, and shutters at *d*, which can be turned back or closed according to the weather. The vapour that escapes from the surface of the brine contains about one per cent. of salt; and the portion that condenses and trickles down the sides of the chimney *s* is collected in a channel, *t*, and conveyed to a tank.

Salt lakes in some parts of the world are used as a source of salt. In the steppes of Asiatic Russia salt lakes are numerous, and their waters hold so much salt in solution that the action of the summer heat is sufficient to crystallize a portion of it; and the crystals, being carried to the banks by the action of the waves, form immense shoals of salt. The Dead Sea, fig. 562, contains a larger proportion of salt than the waters of the ocean. When agitated by wind, the surface has the appearance of foaming brine; and the spray, evaporating as it falls, leaves incrustations of salt upon the clothes, and coming in contact with the skin produces a pricking sensation, very painful to the eyes, nostrils, and lips. The northern shore is very barren; branches and trunks of trees are scattered about, some charred and blackened, others white with an incrustation of salt. The water is also described as being greasy to the touch. On the southern shore, in the neighbourhood of Usdom, is a pillar of solid salt, fig. 557; it is capped with carbonate of lime. Fig. 559 is one of the ravines at the southern end of the sea.

Sea-water is a convenient source of salt to persons residing on or near the coast. The saline matter of sea-water varies from three to four per cent., and of this quantity common salt forms nearly two-thirds. An economical method of evaporating the water is by means of *salt gardens* or *salterns*, fig. 561, which are laid out upon a clay soil on the coast, and worked during the summer months, from about March to September. In these salterns the sea-water is exposed in a series of shallow ponds to the action of the sun and of the air; and as the water is evaporated, the salt is deposited in the hindermost pools, while the foremost ones receive fresh supplies of sea-water. The collecting pond A is filled at the flow of the tide by means of a flood-gate, and the water, having deposited its mud, is conveyed by a pipe to the first series of pools, B; from these, by means of a channel, *c*, it is circulated through a canal, which passes round the remaining pools. From this it enters at D into the ponds at E, then into F, and, lastly, through the open channel *h*, to a third series of ponds, G. During all this time evaporation has been going on, and salt begins to form in the hindermost of these reservoirs. When a crust of salt has formed on the surface G, it is collected by means of rakes into small heaps, *i*, on the sides. When no more salt separates by crystallization, the lye is allowed to run through K into the sea. The chief impurity of the salt thus collected is chloride of magnesium, which absorbs moisture and flows off; for which purpose the smaller heaps, *i i*, are made up into larger heaps, J, and these are thatched with straw and left for a time. The tools used in forming these heaps are shown in fig. 560. Since the duty has been taken off salt, the Cheshire manufacturers have been able to produce the article at so low a price that salterns cannot compete with them. In the year 1856, the quantity of salt exported amounted to 29,820,481 bushels, of the declared value of 401,240*l.* sterling.

XXX.—SODA.

The enormous demand for common salt for curing provisions, and for giving a relish to our food, does not cease with those uses. Great quantities of salt are used in furnishing chlorine to bleaching powder; and still larger quantities in the production of carbonate of soda, which enters into the composition of glass, of soap, and of several other chemical manufactures.

Between the years 1805 and 1823 there was a duty of 15*s.* per bushel on common salt, so that its use was limited almost entirely to the purposes of food. Most of the carbonate of soda was then obtained from *barilla*, an ash produced by burning marine plants. For this purpose the *salsola soda* was largely cultivated on the southern coast of Spain, as was the *salicornia* on the southern coast of France: while on the coasts of Ireland, and the western coasts and islands of Scotland, an inferior article, named *kelp*, was produced by burning the *Fucus vesiculosus* and other species of fucus. The repeal of the duty on salt placed that abundant article in the hands of the chemist, who soon discovered a method of decomposing it, so as to get rid of the chlorine and retain the soda. The first part of the process consists in converting common salt into a rough sulphate of soda. This is done in reverberatory or *decomposing* furnaces, a number of which are arranged side by side, fig. 564, all discharging their flues into a tall chimney. The interior of one of these furnaces is shown in fig. 563. In the division A, called the *decomposing bed*, the salt and the sulphuric acid are brought together: the charge of salt may be from five to six cwt., and an equal weight of sulphuric acid (not concentrated, but of the specific gravity 1.6) is slowly poured in through a leaden syphon funnel, B; the mixture is stirred up with an iron rake covered with sheet lead, and on the application of a gentle heat abundant fumes of hydrochloric acid are liberated, which, passing up the chimney, are discharged into the air in the form of a white cloud of acid, which rains sterility on the adjacent country. Of late years, however, these acid fumes have been made to pass through towers filled with coke, through which water is constantly trickling; the hydro-

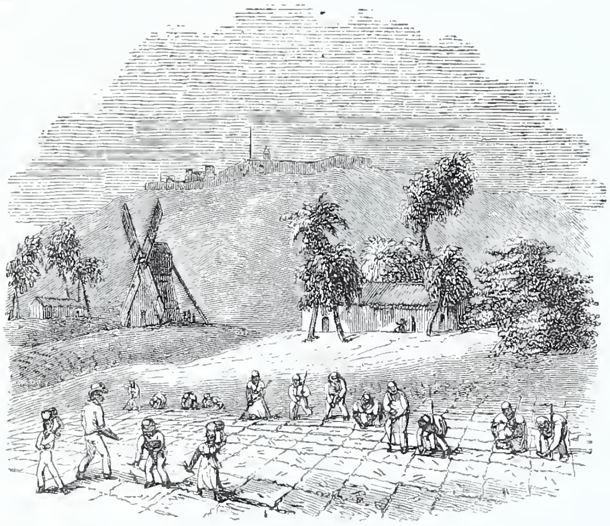
chloric acid, which is very greedy of moisture, is thus absorbed and got rid of. In the bed A of the furnace, about half the hydrochloric acid is expelled from the salt. The pasty mass thus produced is pushed out through an opening into a vault C, and another charge is introduced into A. The pasty mass is now removed from C into the other compartment of the furnace nearest the fire, called the *roasting bed* (D), where it is exposed to a much higher temperature, and in an hour or two loses its remaining hydrochloric acid. The mass is now called *salt-cake*, and it is raked out of D to make room for another charge. The object of the next process is to convert the salt-cake or sulphate of soda into carbonate of soda; which is done by heating it to redness with coal or charcoal and carbonate of lime. The salt-cake is therefore mixed with chalk and powdered coal in the proportion of three parts sulphate of soda, three of chalk, and two of coal; and is thrown in quantities of about 2½ cwt. at a time into a reverberatory furnace, called the *black ash furnace;* which is oval in shape and divided into two parts, one of which, the farthest from the fire, called the *preparing-bed*, is higher than the second division, called the *fluxing-bed.* When the charge is sufficiently heated, it is transferred from the one to the other; and towards the end of the process the mass melts, and appears to boil, from the escape of carbonic oxide gas, which burns with a greenish or yellow flame, forming what the workmen call *candles.* At length, after briskly stirring, the mass is completely fused, and is raked out into cast-iron troughs or wheelbarrows, where it becomes solid, and forms what is called *ball-soda* or *black ash.* It contains about twenty per cent. of pure soda, mixed with unburnt coal, and a compound derived from the sulphuric acid of the salt-cake and the calcium of the chalk (lime, which is the basis of chalk, being an oxide of calcium), called oxy-sulphide of calcium. This last-named substance, known to the manufacturer as *soda-waste*, is a worthless bulky substance, constantly accumulating in the neighbourhood of alkali works, and rendering it necessary to purchase land merely to accommodate it. A cheap method of recovering the sulphur from it would be a great boon to the manufacturer. In order to extract the salts of soda from the black ash, it is broken up into coarse fragments, and digested with warm water for six hours in vats furnished with false bottoms (fig. 565); and the washing is carried on until the soluble matters are extracted, the last washings being used for acting upon fresh portions of black ash. The solution thus formed is allowed to settle, and is then pumped up into large shallow iron pans for evaporation. Heat is applied, and a good deal of the salt crystallizes during the boiling, and is removed by means of perforated ladles. To convert the caustic soda contained in the solution into carbonate, it is evaporated to dryness, mixed with sawdust, and roasted in a furnace called the *white-ash furnace.* Most of the sulphur escapes in the form of sulphurous acid; and the residue yields the soda ash or alkali of commerce, which contains about fifty per cent. of pure caustic alkali. It is ground under millstones, and is sufficiently pure for most of the manufacturing applications of soda; but for the manufacture of plate glass, and for furnishing crystals of carbonate of soda, the ash is further purified by being again calcined at a moderate heat. The carbonate thus obtained is re-dissolved; the liquid is allowed to settle, and while hot is run into hemispherical pans (fig. 566) of cast iron. In the course of five or six days, large well-formed crystals appear; these are broken up, and the *mother-liquor*, or that portion which refuses to crystallize, is allowed to drain off by withdrawing a plug in the bottom: this is evaporated to dryness, and the residue, containing about thirty per cent. of alkali, is fit for use in the manufacture of crown glass and of soap.

XXXI.—SULPHURIC ACID.

The applications of sulphuric acid in manufactures are so numerous, that the consumption of sulphur may be taken as a sort of index of our commercial prosperity. By far the largest supply of sulphur is obtained from Sicily; and we can understand the motives which made our Government, a few years ago, resolve to go to war with Naples, in order to abolish the sulphur monopoly, which that Power had attempted to establish in the face of existing treaties. There is abundance of sulphur in many of the mineral productions of this country; such as gypsum, or sulphate of lime; heavy spar, or sulphate of baryta; galena, or sulphuret of lead; iron pyrites, or sulphuret of iron, &c.; but it is cheaper to import sulphur from Sicily than to obtain it from these sources. In that country, it occurs in the *native* or uncombined state, in beds of a blue clay formation, occupying the central half of the south coast, and extending inwards as far as the district of Etna. The excavations made for getting out the sulphur resemble a quarry: the fragments of sulphur, as they are got out, are collected into a heap and melted in furnaces resembling cauldrons, six or seven feet in diameter, and four or five feet in depth, by which means the sulphur is separated from the clay, calcareous stones, and gypsum, and while in a liquid state is run into wooden moulds of the form of a large brick. The crude sulphur is more economically distilled in the furnace represented fig. 571. Two rows of earthen pots, *a a*, are arranged in a close furnace upon supports, so that the necks of the pots can be let into the top of the furnace while the mouths are left free; the pots can thus be charged from the outside, and then be closed with lids cemented on; after which the fire is lighted and the distillation commences. The vapours of sulphur pass over by the side tubes to the receivers, *b b*, outside, where they condense to liquid sulphur, which flows into tubs of water. *Stick* or *roll* sulphur, or common *brimstone*, is chiefly obtained during the roasting of copper ore, or from iron pyrites; the fumes being received into a long brick chamber, where the sulphur is deposited: it is afterwards purified by being melted in pots, in which some of the impurities rise to the surface and are skimmed off, while others sink to the bottom, and the purer portion is poured into cylindrical moulds of beechwood. The third form in which sulphur is met with is that of a harsh, yellow, gritty powder, known as *flowers of sulphur.* It is obtained by *sublimation*, a process in which a solid is converted into vapour by heat, and then suddenly solidified by cold. It differs from distillation, in which the vapour distilled is condensed by cold into a liquid. Flowers of sulphur are prepared by heating crude sulphur in a vessel which communicates with another of large capacity, such as a chamber of brickwork, the walls of which being kept cool, and the process conducted slowly, the sulphur condenses in powder.

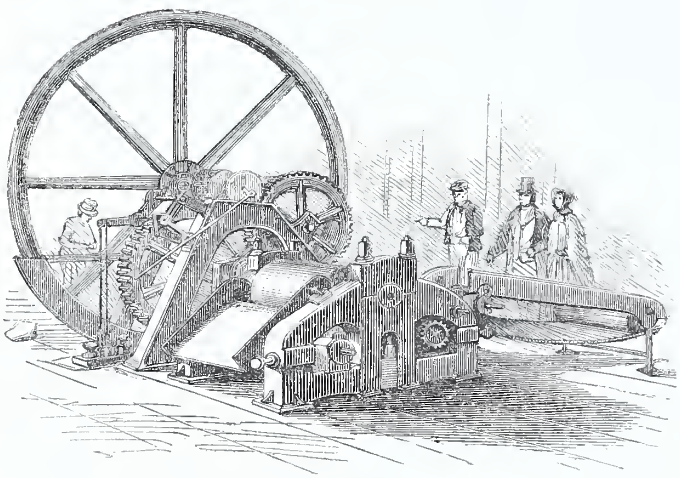
When sulphur is heated in the air to the temperature of 450° and 500°, it burns with a blue flame, and, combining with a portion of the oxygen of the air, gives off pungent suffocating fumes of sulphurous acid. At 239° it melts, forming a yellow liquid: on increasing the temperature, its colour changes to yellowish brown, and at last becomes nearly black and opaque. At 350°, it loses its fluid character, and becomes thick and pasty. At about 500°, it once more liquefies, and if poured into water it foms into a ductile mass, capable of being drawn out into long threads: at this temperature, it may also be used for making casts and receiving impressions of seals, &c. It boils at about 824°. Sulphur is quite insoluble in water; but boiling oil of turpentine dissolves it. The specific gravity of sulphur is 1.95, or nearly twice as heavy as its own bulk of water.

The quantity of brimstone imported into the United Kingdom in the year 1856 amounted to 1,417,807 cwts. The chief demand for sulphur is in the preparation of sulphuric acid, gunpowder, lucifer matches, rockets, and fireworks. It is also used in

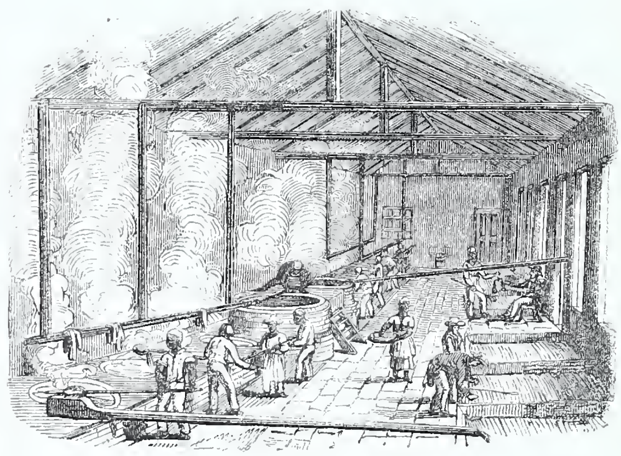


576. PLANTING THE SUGAR-CANE.

577. THE CANE HARVEST

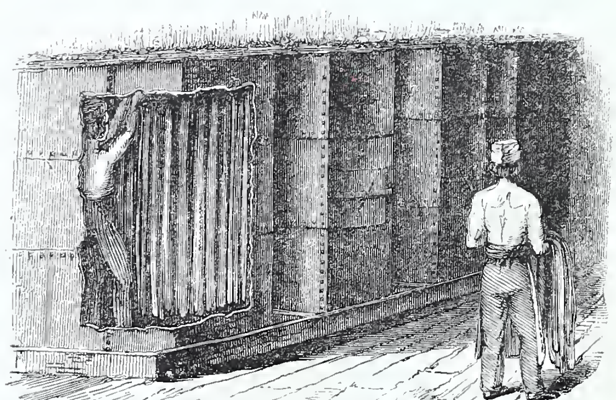


578. CANE-MILL.

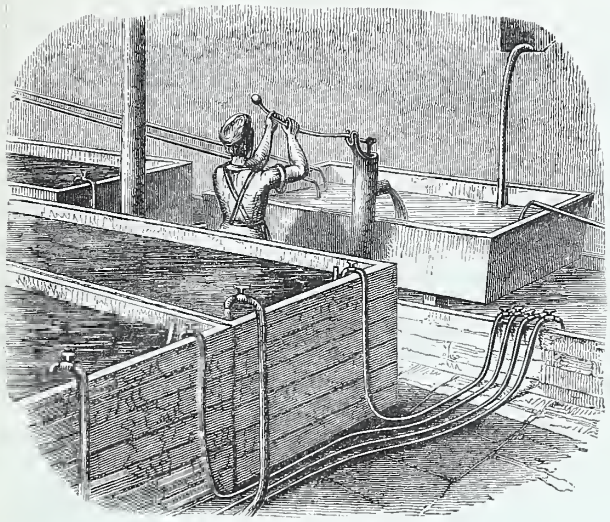


579. THE BOILING-HOUSE.

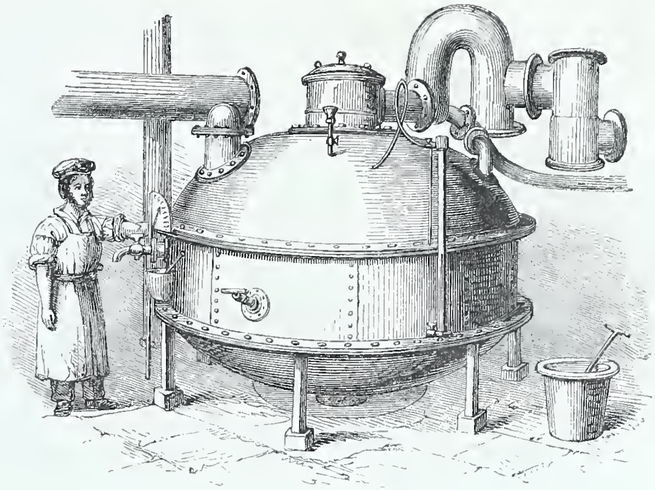
580. BLOW-UP CISTERNS.



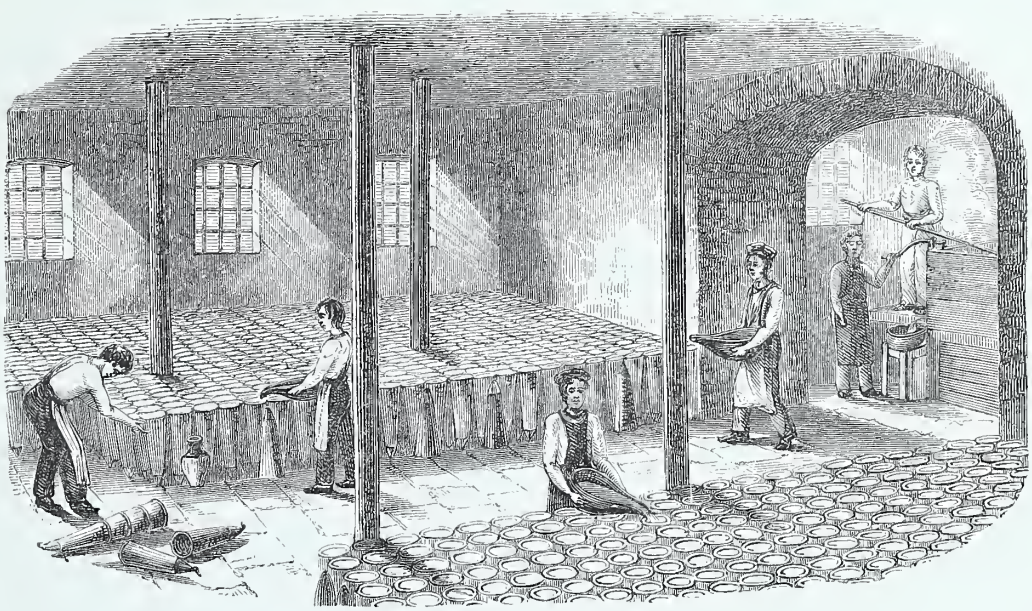
581. BAG FILTERS.



582. CHARCOAL FILTERS.



583. THE VACUUM PAN.



584. THE FILL-HOUSE.

585. SUGAR OVEN.

586. PROOF STICK.

587. TURNING OFF.

medicine, in the manufacture of vermilion (which is a compound of sulphur and mercury), for bleaching straw and flannel, and for some other purposes.

It has been already stated that when sulphur is burnt in the open air, it unites with oxygen, and forms sulphurous acid; or, in other words, one part of sulphur unites with two parts of oxygen. Sulphuric acid, which consists of one part sulphur united with three parts of oxygen, is not so easily produced: in fact, in order to make the sulphur, in burning, take up three instead of two proportions of oxygen, extensive chambers or houses, fig. 574, are erected, varying from sixty to two hundred feet in length, and of proportionate height and width. The chambers are lined internally with sheet lead, that being one of the few substances which are not corroded by sulphuric acid at ordinary temperatures. When sulphuric acid was first manufactured, about a century ago, the materials were burnt in glass receivers, containing a few pounds of water, as in fig. 567, and the acid produced was sold at about two shillings and sixpence per lb. It is now made in the vast chambers already referred to, and is sold for less than a farthing a pound.

Four substances are used in the production of sulphuric acid: 1. Sulphurous acid, produced by the combustion of sulphur in air. 2. Nitric acid, from which the sulphurous acid obtains an additional supply of oxygen. 3. Atmospheric air, which must be constantly renewed. 4. Water or steam, for dissolving the sulphuric acid as fast as it is formed. The sulphur which supplies the sulphurous acid is burnt in a small furnace A, at one end of the chamber, fig. 573: immediately over the burning sulphur is an iron pot, supported on a tripod, containing nitre, mixed with sulphuric acid: the heat of the burning sulphur drives off the nitric acid from the nitre, and the sulphurous acid and the nitric acid vapours are conveyed into the chamber by the wide tube *p*. At the same time, steam supplied by the boiler B is conveyed by the tube *t*, and enters the chamber in the form of jets. The chemical changes that take place within the chamber are somewhat complicated. Sulphurous acid is capable of taking up more oxygen from moist air, and of forming sulphuric acid; but the process is a very slow one. It takes oxygen, however, rapidly from nitric acid (nitrogen + 5 oxygen), and reduces it to the state of nitric oxide (nitrogen + 2 oxygen), a gas which, by mere exposure to the air, takes up an additional supply of oxygen, and forms nitrous acid (nitrogen + 4 oxygen). Now it is remarkable that the sulphurous acid readily takes an additional supply of oxygen from this nitrous compound in the presence of moisture; so that two more portions of sulphurous acid thus become converted into sulphuric acid, and the nitrous compound is brought back to the condition of nitric oxide, in which it is again fitted to rob the atmospheric air of its oxygen, and thus to continue the action. Hence the nitric oxide becomes a carrier of oxygen, continually taking it from the air of the chamber, and giving it up to the sulphurous acid, so that a comparatively small quantity of nitre is sufficient to convert sulphurous into sulphuric acid. The nitrogen of the atmospheric air is discharged by the chimney C, while the sulphuric acid, condensed by the steam, accumulates on the floor of the chamber W. A sample of the acid may be taken out by making an opening in the side near the bottom of the chamber, by pushing the lead inwards, and prolonging it so as to dip beneath the surface of the liquid, as in fig. 570, and prevent the escape of gas. As the waste products of the chamber, in escaping by the chimney C, fig. 573, take with them some of the valuable nitrous compounds, arrangements have been made for retaining them by passing them through a refrigerator immersed in a tank of water at G, fig. 575, from whence they ascend into tall, cylindrical chambers, H, filled with coke, and resting on a grating below, so that the gas has to filter through it before it escapes into the atmosphere. The coke is kept constantly wet with strong sulphuric acid, supplied from the reservoir I. The coke is kept wet by a sudden gush of liquid, which is renewed at regular intervals by allowing a constant stream from I to flow into *j*, which is shown on a larger scale in fig. 568. Here the syphon *a b c* has its longer limb passed through the bottom of a cup, so that in filling the cup no liquid will run out until it rises above the bend at *b*, when the liquid in the cup will flow out at a gush, until it is reduced to the level *a*. This intermittent flow of acid, trickling down through the column H, absorbs nearly all the nitrous compounds which escape from the chamber, so that scarcely anything but pure nitrogen is discharged into the air: the acid then flows down the small pipe *k* into the receiver L, from whence it can be raised into the reservoir O simply by admitting high-pressure steam from the pipe *m* into L, when the acid is pressed up the pipe *n* into O. From O it is made to flow by another syphon cup, similar to fig. 568, into other columns of coke D, E, where it meets with the fresh sulphurous acid gas generated in the furnace A, on its way to the first chamber. The effect of this is to separate the nitrous compounds from the acid which is trickling down through the coke. In order to delay the passage of the sulphurous acid, the column of coke is divided by a stream, so that the sulphurous acid generated in A passes up C, down the column D, up the column E, and so into the first chamber, where it meets the jet of steam F, generated in the boiler B. In fig. 575, the ends of the first and last chambers only are shown, the intermediate chambers being omitted; *f f* also represent jets of steam.

During these complicated changes, the sulphuric acid continues to be formed, and to trickle down the sides of the chamber to the bottom, gradually increasing in density. When the specific gravity of the acid has reached 1,450 (or, in other words, when a bottle which holds 1000 grains of pure water, being filled with the acid, such acid weighs 1,450 grains), it is drawn out of the chambers, and evaporated in shallow leaden pans, until, by throwing off a portion of its water, its density is 1.720. In order further to concentrate the acid, it must be heated in glass or platinum retorts, until white fumes of the acid begin to appear. It is now a dense, oily-looking, colourless liquid, of the specific gravity 1.842. It has no smell; but, from its powerful attraction for moisture, it chars and blackens most organic substances that it comes in contact with. When mixed with water, it becomes exceedingly hot, from the condensation that takes place; the two liquids occupying less bulk than they did before being mixed. If a portion of the acid be exposed to the air in a shallow dish for a few days, it will double its weight by absorbing moisture. The acid is removed from the retorts by means of a lead syphon (fig. 569), in which the end of the shorter arm *a* is turned up: this syphon is first inverted and filled with water; and the long end *b*, being closed with the finger, the short limb is inserted into the body of the retort. On removing the finger, the water in the syphon is set in motion, bringing after it the acid: the water is caught in a small cup, which is removed the moment the acid begins to appear. It falls into the vessel placed for its reception, in a smooth, quiet stream, resembling oil; whence originated the old name of *oil of vitriol*, applied to this acid. It is transferred to large globular green glass bottles, called carboys, packed in straw in wicker baskets, and thus sent to the market.

In large works, it is found more economical to concentrate the acid in stills made of the metal platinum than in glass stills, which are liable to break by the heat, and entail loss of acid, and danger to the operatives. A platinum still, with its appendages, will cost about 80,000 francs, or 3,200*l*. sterling (for these stills are nearly all made in Paris). When the acid is sufficiently concentrated, it is removed by means of the syphon, fig. 572. The leg *a* is plunged nearly to the bottom of the still, the stop-cock *b* is closed, and the worm is filled with cold acid through the funnel C. The stop-cock to this funnel is then closed, and *b* suddenly opened, when the acid thus set in motion draws out the contents of the still. The acid is cooled by keeping the worm immersed in cold water, a supply of which is introduced into the vessel V, by the pipe *t*, which supplies the colder and heavier water to the bottom of the vessel; while the water heated by the worm escapes at the opening *f*.

XXXII.—SUGAR.

Sugar is a common product of the vegetable kingdom, and forms an article of nutriment to most plants at some period of their growth. There are four principal varieties of sugar, the most important of which is *cane* sugar, the ordinary product of the sugar cane. The second, known as *fruit* sugar, is the principle of sweetness in most acidulous fruits; it does not crystallize like cane sugar, but forms a syrupy liquid, which is abundant in treacle. The third variety, known as *grape* or *starch* sugar, is often formed from the second variety, and may be noticed in old dried fruits, such as raisins and figs, where it forms in hard granular sweet masses: it may also be prepared artificially by boiling starch with a dilute acid. The fourth variety, known as *milk* sugar, is that to which milk owes its sweetness. These varieties of sugar consist of nothing more than charcoal and water in a state of chemical combination: thus, cane sugar contains 72 parts of carbon and 99 of water; fruit sugar contains the same quantity of carbon and 108 parts water; while in starch sugar there are 126 parts of water. Cane sugar is much sweeter than the other varieties. As much as $2\frac{1}{2}$ lbs. of starch sugar would be required to equal in sweetening effect 1 lb. of cane sugar. Confining our attention, therefore, to the latter article, which is distinguished from the others by its crystalline character, we proceed to state some of its properties, and the mode of manufacture. In its pure form, as in loaf sugar, it consists of a collection of minute transparent crystals, which reflect and refract the rays of light within it so as to produce the effect of dazzling whiteness: when a lump of sugar is broken, it emits an electric spark, which is visible in the dark; and when two pieces are rubbed together, a pale violet phosphorescent light is visible in the dark; its specific gravity is 1.6; it is soluble in about one-third of its weight of cold water, and in a much smaller quantity of boiling water. On evaporating the viscid syrup thus formed, fine crystals of *sugar candy* are deposited. A solution saturated at 230° (that is, sugar stirred in until the water will dissolve no more) forms in cooling a granular mass; but when the solution is rapidly boiled down until it acquires a glass-like texture on cooling, it forms *barley sugar*, so called from its having been formerly made by rapidly boiling down a concentrated solution of sugar in barley water, heating the mass and cutting it while hot into strips, rolling the strips into cylinders, and then giving them a spiral twist. The candy does not long retain its vitreous and transparent appearance; but it soon acquires a fibrous or granular texture, and becomes opaque. The show sticks in the windows of grocers are made of coloured glass, which resembles barley sugar in its freshest state.

The sugar-cane (*Saccharum officinarum*) is a perennial plant belonging to the family of the Grasses; it varies in height from six to fifteen feet, and has a diameter of from one and a half to two inches; it has a knotty stalk, and at each knot or stalk is a leaf and an inner joint: the number of joints may vary from forty to sixty, and even eighty in the Brazilian cane. The cultivator distinguishes three kinds of cane:—1, the *Creole* cane, with dark green leaves and a thin but very knotty stem; 2, the *Batavian* or *striped* cane, with dense foliage, and covered with purple stripes; and 3, the *Otaheite* cane, which grows luxuriantly, is the most juicy, and yields the largest product. It is chiefly cultivated in the West Indies and South America. The sugar-cane was originally a bog plant, and requires a moist nutritive soil and a hot tropical climate. It is propagated by slips, or pieces of the stem with buds on them; these are planted in holes from fifteen to eighteen inches square and from eight to twelve inches deep (fig. 576). It takes from twelve to sixteen months before the plant arrives at maturity. When the canes are ripe, they are cut, and the roots strike again and produce a fresh crop; but in about six years they require to be removed and fresh ones planted: the canes which grow immediately from the planted slips are called *plant-canes*, while the sprouts from the old roots or stoles are named *rattoons*. The canes should be cut as close to the stole as possible, the juice of the lower joints being the richest; the cane top, with one or two joints, is also cut off, when the canes are tied up in bundles (fig. 577) and sent to the crushing-mill (fig. 578). This consists of cast-iron rollers, worked by means of toothed wheels attached to the axles. The cane is crushed by the first pair of rollers, and the juice is expressed by the second pair; the juice passes into a channel below, and then flows away to a reservoir. The crushed cane, called *cane-trash*, is used as fuel in the boiling-house, and the ashes are returned as manure to the cane plantation. The juice is clarified by means of heat, which coagulates the albumen, and by the addition of lime, which neutralizes the acid and renders some of the solid impurities insoluble. The old method of applying heat was by means of iron boilers, called *teaches* (fig. 579). The juice is conducted from the juice-reservoir, below the crushing mill, into the clarifying pan; which is the largest, and situated farthest from the fire. The proper dose of milk of lime, or *temper*, as it is called, is added; when a thick scum collects on the surface, and is removed by skimming. The juice is passed through four other teaches, and heated until the evaporation is complete, the scum being removed from each and passed into the molasses cistern, and is used for making rum. The scum consists of nearly pure sugar, decomposed by heat, together with the natural impurities of the juice. The syrup is known to be sufficiently concentrated in the last teach, when on taking up a small portion between the finger and thumb it can be drawn out into a thread of about half an inch in length. The syrup is then transferred to coolers or shallow open vessels, fig. 579, and in about twenty-four hours the sugar *grains*, that is, forms into a soft mass of crystals embedded in molasses. The sugar in the coolers is frequently stirred with iron rods to equalize the temperature; and it is then removed to the *curing house*, and placed in hogsheads or *potting casks*, which rest on an open framing over the molasses reservoir, a large cistern lined with lead. The bottom of each cask contains holes an inch in diameter, into each of which is thrust a plantain stalk, extending to the top of the cask; when, in the course of a few weeks, the molasses gradually drain away, leaving the crystalline portion of the sugar tolerably dry. There is a further drainage of molasses in the hold of the vessel after the casks have been shipped. Such is the *raw* sugar of commerce: it consists of a crystalline flour of pure sugar, moistened throughout with molasses, varying in quantity, but often containing one-third of its weight of that substance. Of late years, improved methods of evaporating the juice have been introduced, so that the system is not liable to the satirical remark which defined the old method as "an elaborate and effectual means of converting pure sugar into molasses and scum." The new system consists in the application of a regulated steam heat where heat is required; separating solid matters from the juice by means of filters or flannel, or of animal charcoal; and evaporating either by means of the *vacuum pan*, or in open pans containing a coil of steam pipe.

The manufacture of refined sugar in this country originated in the defective methods of preparing raw sugar in our colonies. It is still carried on to a large extent, in order to produce that beautiful variety of sugar known as lump or loaf sugar, which is probably used more or less in every house in the kingdom. The raw sugar from the West Indies, America, and the East Indies is imported in cases; that from Jamaica, St. Domingo, and St. Croix in hogsheads; from Manilla and the Mauritius in double sacks,

plaited or woven from the leaves of reeds; the man in fig. 580 is bringing in a sack of this kind. In the year 1856, the quantity of unrefined sugar imported into the United Kingdom amounted to 7,240,626 cwts: of refined sugar and candy 258,929 cwts., and of molasses 942,223 cwts. The quality of *raw* sugar varies from white Havannah, which is almost equal to loaf sugar, to the dark brown, moist, sticky, and smeary characters of the worst varieties. But whatever the character of the sugar, the first operation of the refiner is to dissolve it in water. For this purpose the sugar is emptied on the floor, as in fig. 580, and the hogshead is inverted over an arched copper; while a jet of steam directed into it removes whatever sugar adheres to the staves. From the floor the sugar is shovelled into cisterns, named *blow-up cisterns* from the fact that a perforated steam pipe, fixed at the bottom of the pan, blows up steam through the water and completes the solution. The solution is clarified by stirring in a small portion of blood and ground animal charcoal, together with some lime-water for neutralizing the acid. The solution is stirred up with oars; and the albumen of the blood, dispersed through the solution, entangles and thus collects small mechanical impurities, and, coagulating by the heat, forms into large connected flocks, easily separable by strainers: it also forms with the charcoal a compact scum, which can be readily removed. Other mechanical impurities coated with albumen are separated by passing the solution through bags hung up in square vessels of iron, the top of which contains reservoirs for the concentrated solution obtained from the blow-up cisterns. In fig. 581 a portion of the iron case is removed to show the man engaged in fastening up the bags. The syrup, after it has run through the filters, is of a reddish colour, and is next passed through beds of animal charcoal, prepared by calcining bones in close vessels and reducing them to a coarse powder. The filters, fig. 582, consist of large vats twelve or fourteen feet in depth, with perforated false bottoms; these are covered with ticking, and the charcoal is then put in to the depth of twelve feet; above this is another layer of ticking, covered with a perforated metallic plate. The syrup is then poured over the surface, and by the time it has run through the filters, it has been deprived of colour by the curious attraction which exists between colouring matter and bone black. The syrup, now called *liquor*, is passed into the reservoir for supplying the boiler. The old method of concentrating the liquor to the point required for crystallization was by raising it in open vessels to the temperature of at least 230°; but at this point, and under the influence of the air, sugar quickly passes into molasses, or uncrystallizable sugar. By excluding the air, liquids will boil at a much lower temperature than when they are exposed to atmospheric pressure. Thus water, which boils under ordinary circumstances at 212°, will in vacuo boil at 90° or 100°; so also a solution of sugar which requires 230° under atmospheric pressure will, if that pressure be absent, boil at 150° or 160°. This is what is done in the vacuum pan, fig. 583; which consists of a large copper boiler of a spheroidal form, to enable it to resist the crushing pressure of the external air, which is equal to about fifteen pounds on every square inch of surface; and the pressure of the air from within is removed by means of a powerful air-pump: the lower half of the pan is double, for the purpose of admitting steam to heat the pan; and there is also a coil of steam pipes within the pan for assisting the evaporation. By continuing to work the air-pump, vapour of water which rises from the liquor is pumped out; so that the liquor can be kept boiling at a moderate steam heat. The attendant watches the progress of the concentration by means of a proof stick, fig. 586, which consists of a cylindrical rod, exactly fitting a hollow tube, which enters the pan in a slanting direction. The upper end of the rod is open; but the lower end, which dips into the syrup, has a slit on one side of it about half an inch wide: within this tube is another shorter tube, which can be moved round in it through half a circle; near the lower end of this tube is a hollow, which corresponds with the slit in the outer tube. By making the slit and the cavity coincide, the latter is filled with sugar; and by turning the stick round through half a circle, the slit is covered by the fixed tube, and the inner tube can be withdrawn without allowing air to enter the pan. When it is ascertained, by drawing out a thread of the syrup between the finger and thumb, that the liquor will deposit its crystals on cooling, the air-pump is stopped, air is admitted into the pan to equalize the pressure, a plug at the bottom of the pan is opened, and the syrup flows into a receiver in the room below. In this vessel, a portion of which is seen at the right of fig. 584, the syrup is raised to the temperature of 180° or 190°, twenty or thirty degrees higher than it was in the vacuum pan, in order to prevent crystallization before the sugar is placed in the moulds. To assist this object, men are employed in stirring up the syrup with poles. The conical sugar moulds are made of brown earthenware or of sheet iron; there is a hole in the pointed end which is first stopped with paper; and these moulds being set up, as shown in fig. 584, are filled from the heater by means of copper basins, and the sugar is stirred up in each mould in order to get rid of air bubbles, which would give the sugar a honeycomb appearance. The moulds are left in this condition for about twenty-four hours, and are then removed to an upper floor, where the temperature is maintained at about 80° by means of steam pipes; the paper plugs are taken out, and a wire is passed through the hole to insure an open channel, when the moulds are set in earthen jars or suspended in a framework over a gutter. The syrup which flows off is of a greenish colour, which being collected and boiled over again with raw sugar furnishes an inferior kind of lump; this again furnishes a syrup which supplies a yet lower description of lump; and when all the crystalline particles have been removed, the residue is sold as treacle. The inferior loaves thus produced are often used for making what is called *crushed sugar*, from which the uncrystallized syrup is separated by placing the sugar in a drum mounted on a vertical axis, and giving it a rapid rotatory movement. The drum is formed of stout wire gauze, and is inclosed in a fixed cylinder, in which the liquid syrup is collected. But to return to the sugar which we have transferred to the moulds, fig. 584, and now draining in an upper floor. The sugar is not yet of the proper colour, or of that dazzling white required in the finest variety. The crystals in the mould consist of pure sugar, but there is a good deal of coloured syrup entangled among them. To remove this, a saturated solution of pure sugar is poured into each mould; being saturated, it is incapable of dissolving the crystals, but it thoroughly washes them, and thus gets rid of the coloured syrup. The loaf improves in whiteness from the base to the point every time this operation is performed. When a satisfactory result has been attained, the loaves are removed from the moulds and are arranged in a hot room (fig. 585), which is kept at a constant temperature of about 140° by means of steam pipes. Shape is given to the loaves by passing them through a kind of lathe or a series of cutting blades arranged in a conical form as in fig. 587, after which the loaves are tied up in paper and are ready for the market.

THE END.